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CONTENTS

A PHENOMENON IN VISION SIMILAR TO REFRACTORY PHASE *

By Roland C. Travis

Introduction; method and apparatus; results and interpretation: relationship between the intensity of the stimulus and the refractory period when the observer is relatively dark adapted, relationship between the amount of dark adaptation and the intensity with a constant time between stimuli of 30 seconds, relation between the amount of dark adaptation and the refractory phase when the intensity is kept constant; summary; bibliography.

Introduction

In determining the reliability of an apparatus for measuring threshold values the experimenter noted that when the stimulus,[1] of an intensity at or a little above the observer's threshold, is given, a certain interval of time must elapse before a second stimulus of the same intensity appears as bright or can be seen at all. A relationship was noted between the intensity of the stimulus and amount of time that must elapse between stimuli in order that the second shall cause a visual response. The less intense the stimulus the longer the time required between stimuli to bring about a response to the second. It was noted that if the intensity were a little above the threshold, and the second stimulus were given a short time (10 sec.) after the first, the second appeared greatly decreased in intensity; then, if a third were given after another 10 seconds it might or might not be perceived, and if a fourth were given after the same interval it could not be seen at all. Again if the stimulus were turned on for a period of 10 to 15 seconds, it appeared bright at first, then

* This research was carried on in the psychological laboratory of the psychopathic hospital, State University of Iowa, under the direction of Dr. S. T. Orton, Director.

[1] The stimulus is a white light of very low intensity projected on a screen 4.3 cm. in diameter, 115 cm. from observer. See description of apparatus later in text. A fixation light was used to hold the observer's attention in direction of the stimulus.

suddenly died out continuing not longer than 3 seconds. If the stimulus were left on continuously at an intensity slightly above the threshold (3 units on scale), 30 to 50 seconds must elapse before the observer is conscious of seeing the light again, then it immediately dies out, but appears again in 5 to 10 seconds greatly decreased in intensity and continues a shorter time than before, then it again appears after about 10 seconds still more decreased in intensity, dies out suddenly and does not appear again for 30 to 50 seconds.

This was a constant observation in the case of the experimenter. During the longer period of 30 to 50 seconds all sorts of after-images, light clouds, greys and blackness seem to appear. When the stimulus was periodically turned on and off the after-images and clouds of light were not nearly so pronounced. The method of periodic stimuli was employed for this reason in further experiments on ten observers.

The lapse of time between stimuli necessary to bring about a response to a second appears to be a phenomenon similar to refractory phase of the spinal reflexes of the dog's hind limb described by Sherrington (1) in the scalptor-reflex, the scratch reflex and the extensor thrust. Where certain areas of the skin are stimulated by electrical or mechanical means the response is contraction and relaxation of certain groups of muscles of the hind limb. In these reflex arcs are afferent, efferent and central conduction paths involving several synapses. Each of these reflexes has a refractory phase during which no excitation takes place or the mechanism shows less than its full excitability, regardless of the strength of the stimulus. Internal conditions such as blood supply, fatigue, narcosis and other toxic conditions influence the refractory period to a great extent.

The nature of refractory phase is better brought out in Sherrington's own words (2), " refractory phase appears at the one end and at the other of the animal scale as a factor of fundamental importance in the coördination of certain motile actions. In the lowly animal form (Medusa) it attaches locally, to the neuro-muscular organ, and also in the visceral and blood vascular tubes

of vertebrates. But in higher forms (dog) refractory phase occurs as regards the skeletal musculature, not in the peripheral neuro-muscular organ but in the centers of the nervous system itself."

Mast and Dolley (3) noted in their experimentation on the butterfly that under continuous illumination there are rapidly alternating stimulatory and refractory periods. They conclude that there are probably in the nervous system of the receptors alternate sensitive and refractory periods, the sensitive periods probably varying inversely and the refractory periods directly with the luminous intensity.

The analogy between this observed visual phenomenon and refractory phase of spinal reflexes cannot be carried far, because refractory phase of the spinal reflex is a period during which no excitation takes place or the organism shows less than its full excitability regardless of the strength of the stimulus. This is not true in the case of vision, at least within our experimental limits; because a stimulus of much greater intensity will bring about a continuous sensation, but at a much lower intensity the visual mechanism shows a definite refractory period.

There are several possibilities in explanation of the fact that we are conscious of continuous stimulation in the photopic eye during the day; and yet we are definitely conscious of a refractory period in the scotopic eye under faint stimulation. First, in the light adapted eye several rods or cones, or portions of the nervous relays leading to and from the visual cortex may have alternating sensitive and refractory periods which are of much shorter duration than in the scotopic eye. Second, it may be a function of the cortical arcs of the visual area, these arcs having sensitive and refractory periods with much shorter duration in the light adapted eye. Or, third, it may be a function of the combination of the two factors just mentioned with other factors. That is to say, it is more probably a function of the entire visual mechanism and not a special attribute of any part. These explanations are, of course, somewhat speculative and cannot be verified directly by our experiments.

This visual phenomenon seems similar to refractory phase of spinal reflexes except, (1) that a much greater stimulus will bring about a response in the scotopic eye during refractory period, and (2) that the response in spinal reflexes is muscle contraction and relaxation, whereas in vision the response is conscious recognition of light sensation. The refractory period of the scotopic eye, however, is much longer, more irregular and much more complex than in the spinal reflex. This fact makes accurate experimentation very difficult, because in addition to the very complex mechanism of the visual receptor proper, there is a much more complex mechanism in the nervous relays leading to and from the cortex and in the cortical arcs themselves.

Method and Apparatus

More accurate, detailed and quantitative experiments were made on ten observers, which confirmed the observations made by the experimenter on himself. Three experiments were made on each observer in determining the relationships among the three variables, dark adaptation, intensity of the stimulus and the refractory period. The first experiment was to observe the relation between the intensity of the stimulus and the refractory period of the visual mechanism with dark adaptation remaining as constant as was possible within experimental limits. The second experiment was to observe the relation between the dark adaptation process and the intensity of the stimulus with the time between stimuli kept constant. The third experiment was to observe the relation between the dark adaptation process and the length of the refractory period with the intensity of the stimulus remaining constant.

Two immediate problems arose in getting apparatus suitable for the purposes of the experiments. First, to obtain a sufficient range of intensities to come within the visual range of several individuals. Second, to change the intensity to determine the threshold without changing the color. If the color changes as well as the intensity the result will be a color as well as an intensity threshold. The change in color complicates the situation to a

great extent and adds another source of error. Our first experimental set-up was not free from this error, because the intensity of the light source was varied by varying the amount of current going through the light circuit by a rheostat. As the intensity was varied from high to low the color of the light changed from
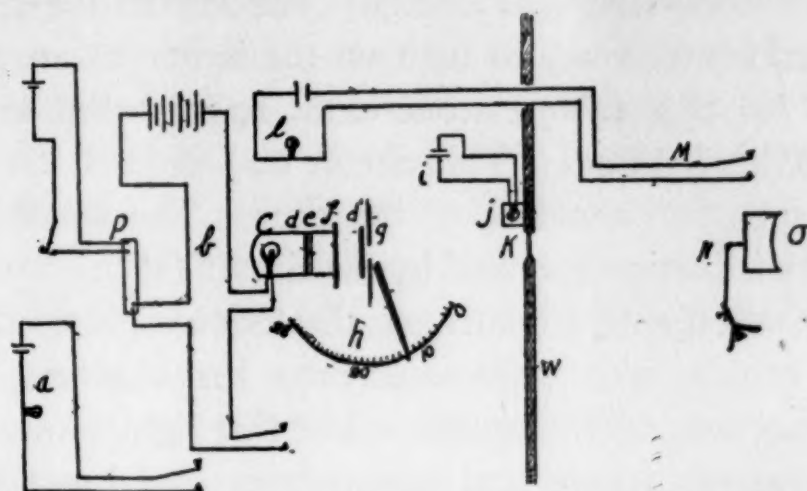

FIG. 1.

a—Dim light circuit to tell time; b—circuit for stimulus light (c) regulated by key and electric clock (p); d—ground glass screen just back of pinhole in sheet metal (e); f—Corning daylite glass screen; d'—ground glass screen just back of iris diaphragm (g); h—objective scale for pointer of iris diaphragm; i—circuit for fixation light (j); k—end daylite glass screen; l—response light regulated by key (m); n—headrest for observer (o); w—wall board between (o) and apparatus.

white to red. To control this factor the color was ruled out by using a white light the intensity of which was controlled by an iris diaphragm.

The accompanying diagram gives the scheme of the apparatus. Interposed between the light source (c) and the observer (o) are a ground glass screen (d), a pin-hole in sheet metal strip (e), a Corning Daylite glass (f), an iris diaphragm (g) which may form an aperture ranging from 3 mm. to 22 mm. in diameter by regulating the lever (h) the position of which may be read on a scale ranging from 0 to 28 steps, just back of the diaphragm may be placed another ground glass screen (d'), and lastly the end screen of Corning Daylite glass (k) 4.3 cm. in diameter inserted in a board 115 cm. back of which the observer sits. The total distance between the light (c) and the observer (o) is 177.3 cm. The distance between the other parts of the apparatus

is as follows: between (c) and (d) 7.3 cm., (d) is immediately back of (e), between (e) and (f) 4.5 cm., between (f) and (g) 6.5 cm., (g) and (k) 44 cm.

The lamp (c) is lighted by 8 Edison-Lelande wet cells of .9 volt each. The light bulb has a rather concentrated filament and is of 6–8 volt capacity and 21 c.p. The key in the circuit (b) is the experimenter's key to turn on the light (c) in giving the stimulus. An adjustable electric clock (p) is used to time the interval between stimuli. The circuit (a) is used to operate a very dim light for ascertaining the time. The small light (j) is the point of fixation operated by the circuit (i).

A complication enters relative to the fixation point. The fixation light can be seen continuously by the observer, and this prevents complete dark adaptation, but this light is necessary to keep the observer's gaze and attention in the direction of the stimulus. As a matter of fact the fixation light made very little difference in the observer's threshold (1 or 2 steps on the scale). The fixation light (j) is lighted by one Edison-Lelande wet cell. The key (m) was used by the observer in making known his response to the experimenter by lighting the light (1). (n) is the headrest; (w) is the board between the observer and the experimenter.

The observer is seated comfortably in a chair quite close to the table on which is firmly fixed the stand for the headrest (n). The headrest is adjustable so that each individual's head can rest comfortably. The key (m) is movable and the observer adjusts its position so that the forefinger of his right hand rests easily on the key. The observer is told to look steadily at the fixation light (2.3 cm. directly above the screen), and every time he is conscious of seeing the light proper, he is to respond by pressing the key. This lights the light (1) and the observer is credited for his response. The lights (a) and (1) are so arranged that none of their rays fall on the screen (k). The entire apparatus is in a light proof room.

It may appear from the experimental set-up that the light coming from the screen 4.3 cm. in diameter falls entirely on the

rod free area of the retina. But previous investigations which will be mentioned later have brought out the fact that the fovea is totally adapted in about ten minutes in the dark, and our subjects required from 19 to 47 minutes for the retina to reach its maximum sensitivity. It is obvious then that part of the rod area as well as the rod free area is being stimulated.

Again we can determine the size of the retinal image made by the screen and compare this determination with the actual size of the rod free area. If we figure on the basis of the standard eye (4), the size of the retinal image is to the size of the object as their respective distances from the nodal point. In the standard eye the nodal point is 7 mm. back of the cornea and 15 mm. in front of the fovea centralis. Then our relation would be: distance from the screen to nodal point is to the size of the screen as the distance from nodal point to retina is to the size of the retinal image, or $1157 : 65 = 15 : x$, or $x = .842$ mm., diameter of retinal image. *Parsons* (5) gives the size of the rod free area as .4 mm. to .8 mm. in diameter, and the fovea centralis as .24 mm. to .3 mm. in diameter. The American Encyclopedia of Ophthalmology gives the diameter of the fovea as being .2 mm. to .4 mm. When the rod free area has the diameter of .8 mm. as the maximum, even then both rods and cones are stimulated in our experiments because the retinal image is .842 mm. in diameter.

The opening of the iris diaphragm is controlled by a pointer which may be set in steps from 0 to 28 as shown at (h). Facilities were not available for accurate measurement of these intensities and the illumination on the screen cannot, therefore, be given in terms of lamberts or candles. According to Hecht's data in his articles on Foveal Dark Adaptation (7) and Adaptation of the Human Eye (8), he gives the luminous intensity on the screen at the observer's threshold after 10 minutes dark adaptation as being 4.06×10^{-4} millilamberts (90 millilamberts equal 0.028 candles per sq.cm.). It required 10 minutes dark adaptation before our subjects could see the light when the pointer was set at 28, thus the brightness at 28 on our scale is probably

about 4.06 × 10⁻⁴ ml. When Hecht's observers were totally
dark adapted the brightness of the threshold intensity was
.07 × 10⁻⁴ ml. apparently comparable to the lower end of our
scale (1 to 10). The ratio of these brightness values from 10
minutes dark adaptation to total adaptation is 58 : 1. That is
if these two investigations are comparable brightness 28 on
our scale is more than 50 times that of 1.

Results and Interpretation

*Relationship between the intensity of the stimulus and the
refractory period when the observer is relatively dark adapted.*
Table I shows the data for the ten observers giving the relation
between the intensity and the refractory period when the observer
is relatively dark adapted. The same relation is brought out
by the same data plotted in Fig. 2. The curves will at once bring
out the general trend. There are striking variations between
different individuals, both as to the intensity and the required
time interval between stimuli. In every case it will be noted,
that as the intensity approaches the observer's threshold the
longer the refractory period becomes, and the greater the intensity
the shorter the refractory period becomes.

It might be well to state here that the condition of dark
adaptation is not absolutely constant. This is true not only
between individuals but in the same individual at different times.
The level of dark adaptation never remains exactly the same from
one moment to the next, especially is this true when the stimulus
is being given. In spite of these minor fluctuations, however, it
is quite possible to obtain the general quantitative relationship
between the intensity and the refractory period by the methods
used in this experiment.

Each observer was required to remain quietly in the dark at
least 20 minutes before the first stimulus was given. The fixa-
tion light was turned on 5 minutes before the stimulus was given
in order that the observer might become adapted to holding his
attention and gaze in the direction of the stimulus. After 20
minutes of dark adaptation the observer was given a stimulus

of rather high intensity (25 points). If no response was made the adaptation was carried still further until a response did occur at this intensity. The stimuli were never closer together than 30 seconds for this preliminary determination, and each stimulus was of 3 seconds duration. When the observer responded to the intensity 25, the intensity was lowered to 10 or 15 depending on how bright the first stimulus appeared to the observer. At this lower intensity a longer time between stimuli was given. This

TABLE I. *The relation between the intensity of the stimulus and the refractory period with dark adaptation constant (the refractory period given in seconds)*

Intensity of stimulus—Iris diaphragm scale.

Observers	1	3	4	5	7	8	10	12	13	15	20	25	28
A....						110	40			35	12	5	1
B....	105		30				10			5	3	1	
C....		100		35			15			5	3	1	1
F....									85	30	10	4	
G....							100			60	30		10
H....						90	75			30	15	10	
I.....				115			70			30	20	4	1
J.....				100	40		20			9	6	4	3
K....									80	30	20	4	3
L....				80		45		35		30	8		1

was found to be necessary because of the relationship existing between the intensity and the time required between stimuli to bring about a response. This relationship was roughly determined previous to the main experiment on the experimenter and three other individuals.

When an intensity was obtained below which the observer failed to respond as the dark adaptation progressed, and the time between stimuli was as long as 120 seconds,[1] this intensity was taken as the observer's threshold. The minimum amount of time required between repeated stimuli to obtain a response at the threshold was then ascertained. This was called the refractory period at the threshold. Then the refractory periods for the intensities for about every five units along the scale were determined up to 28 as will be seen from Table I. The numbers in

[1] 120 seconds was taken as the upper limit for refractory period, because the first three observers made no response to lower intensities when a longer time was allowed.

Table I and the plotted points of Fig. 2 were obtained in the following manner: Observer A's threshold intensity, for example, was 8 and the refractory period for this intensity was 110 seconds. Observer A responded to intensity 8 after a lapse of 120 seconds, also after 115 seconds and again after 110 seconds, but no response was made after the intervals 105 or 100 seconds. Then the interval of 110 seconds was again tried and he responded
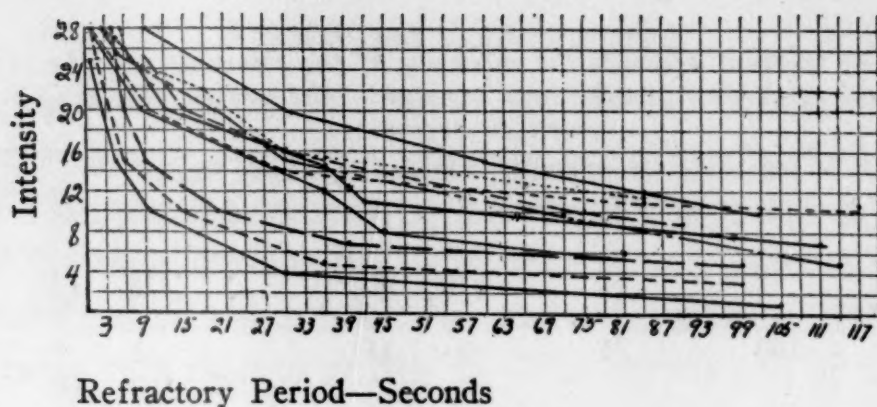

Refractory Period—Seconds

Fig. 2.

10 Observers—Dark Adaptation Constant

twice with 110 seconds as the refractory period. The refractory periods for higher intensities were obtained in the same way, but with more ease and less time because the refractory period becomes shorter with increasing intensities.

After the refractory periods for the different intensities were obtained, the observer was allowed a further period of 10 minutes adaptation in order to check his former threshold. No lowering of the threshold was observed after this period of further adaptation in any of the 10 observers. The data also show that the refractory periods of the 10 observers at the threshold vary from 80 to 115 seconds, and the thresholds vary from 1 to 13. Again, it follows that the greater the intensity the shorter the refractory period, and the lower the intensity the longer the refractory period under conditions of dark adaptation.

The relationship between the amount of dark adaptation and the intensity with a constant time between stimuli of 30 seconds. There are three main structures subject to radical changes in the light and dark adaptation of the human eye. They are, (1)

the pupil or iris, (2) the macula lutea and fovea centralis or the cone area of the retina, and (3) the peripheral retina or the rod area. *Reeves'* (6) investigation of pupillary contraction and dilation by the photographic method showed that the rate of closing of the pupils of 8 observers from completely open to completely closed required 5 seconds time, whereas the time required for the pupils to completely open when the subject was brought from a stimulus of bright sunlight falling on white paper into total darkness was 5 minutes, with 7 observers.

Hecht's investigation (7) of foveal dark adaptation on 15 observers revealed that in the first 30 seconds of adaptation the fovea becomes extremely and rapidly sensitive; and that there is very little if any adaptation after 10 minutes in the dark.

Again in Hecht's analysis (8) of the literature on dark adaptation of the eye one finds that Piper had published complete results on retinal adaptation of 18 subjects. It was brought out in this paper that the changes in sensitivity are remarkably constant, not only in a given individual, but in different individuals as well. Age does not change the regularity of this adaptation, and the effects of drugs is practically negligible. Even those with deficiencies of color vision present a normal type of dark adaptation. The experiments consisted in finding the intensity of a square area of light which was just barely visible to the eye. Observations were made at regular intervals during the stay in the dark. The subject fixed his eyes on one corner of the square of light, so that the most of the light fell on the area outside of the fovea centralis. At first this minimum intensity was large; as the stay in the dark was prolonged it became less and less; and finally it reached a constant minimum. This constant minimum was reached in most cases before 45 minutes in the dark.

It will be noted from Table II that our nine observers varied from 19 to 47 minutes in reaching their thresholds with the constant time of 30 seconds between stimuli. Observer A reached his minimum intensity at 42 minutes, B at 33 minutes, C at 47 minutes, G at 30 minutes, H at 35 minutes, I at 19 minutes, J at 26 minutes, K at 22 minutes, and L at 42 minutes. The average time for dark adaptation of the nine observers is 33 minutes.

Table II also brings out the fact that there is a general decrease in the intensity of the stimulus as dark adaptation goes on.   This

TABLE II. *The relation between the amount of dark adaptation and intensity with a constant time of 30 seconds between stimuli*

Observers

Dark Adaptation—Minutes	A	B	C	G	H	I	J	K	L
				INTENSITY OF STIMULUS					
5						28			
6						24			
7									
8		28							
9		24				18			
10				28					
11				25		10			
12		17		20			28		
13				15			20		
14							15		
15		14	28	15	28			28	
16				13		9			
17	28	10	23	10			12	25	28
18		20					10	20	
19	21	10				8	8	13	
20			15	8	22				
21				5					
22	12		12	3			9	10	
23		6		2	17				25
24	12					9	10		23
25							8	10	
26							6		20
27		7		4			7	10	17
28				3	16		7		14
29				1		11		11	
30	16		13	1			7		
31		7				8			16
32							8	12	14
33		5							
34	12		13			8			15
35			10	1	15			12	13
36			8						
37		7	6						13
38	15						8		
39						8			14
40	11	6		1			7		14
41									
42	8		4		15				12
43						8			13
44									
45	9	5		1			8		
46					18				
47			3						
48									
49									
50									
51			4		15				
52		5							

decrease is not constant, however. There is some waxing and waning in every case, but on the whole there is a very definite general decrease in intensity. Fig. 3 gives the curves for the figures in Table II. There is a very rapid decrease in intensity for the first few minutes in almost every case, and it is also rather constant for the first ten minutes, then the general waxing and waning seems to be the trend of the curves from there on.
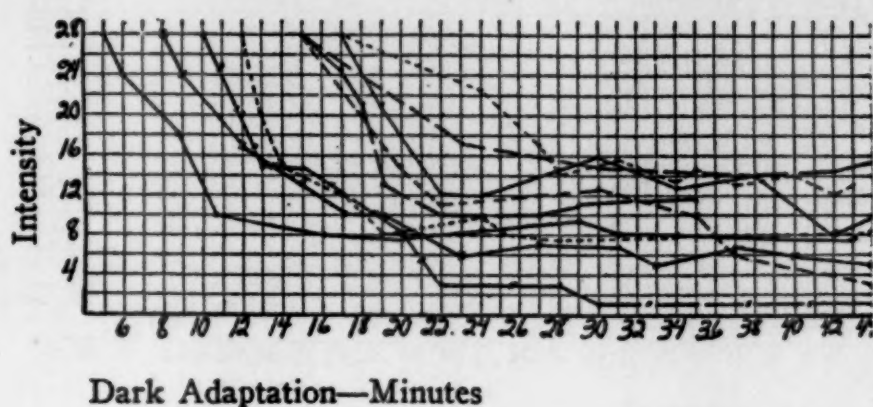

Dark Adaptation—Minutes

FIG. 3.
9 Observers—Interval (30 sec.) between Stimuli

Other factors are involved which we are less able to control in the present experimental procedure, although this waxing and waning of the threshold intensity values is probably due to the interaction between the following three factors: (1) Time between stimuli. At any stage of dark adaptation and with intensities near the threshold, the time which must elapse after one stimulus before a response is produced by a second appears to be inversely proportional to the intensity; (2) Intensity. With a constant time interval, the threshold value of a given intensity varies inversely as the amount of dark adaptation. (3) Dark adaptation. As dark adaptation progresses the intensity of a stimulus required to bring out a response at a constant time interval is progressively less, and with a stimulus of given intensity the time interval required between stimuli to give a sequence of responses is progressively shorter.

The relation between the amount of dark adaptation and the refractory period when the intensity is kept constant. Table III gives the data obtained from 9 observers on the relation between

the amount of dark adaptation in minutes and the time in seconds
that must elapse between stimuli to bring about a response when
the intensity remains constant in each case.　Fig. 4 gives the
curves for the data in Table III.　The relation between refractory
period and the amount of dark adaptation is one of inverse ratio
when the intensity remains constant and is barely visible to the
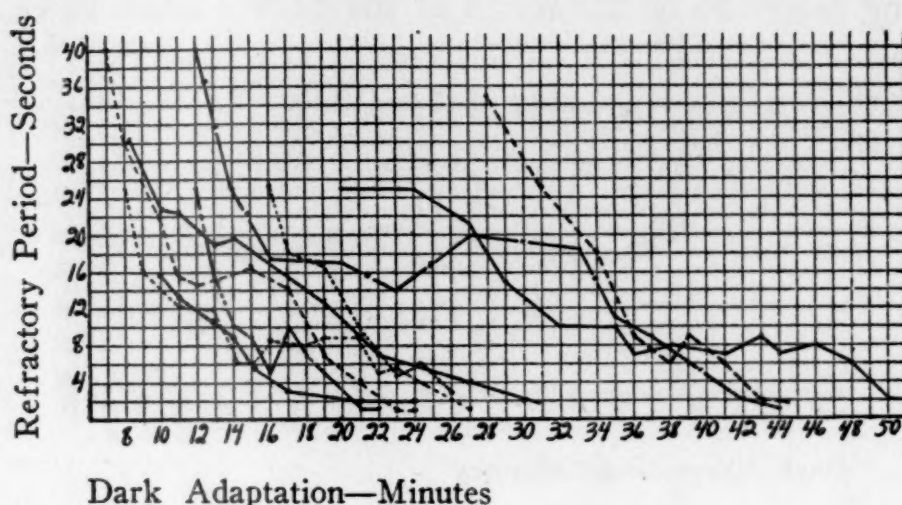

Dark　Adaptation—Minutes

Fig. 4.
9　Observers—Constant　Intensity

eye in the beginning of the dark adaptation process.　This will
be noted from the curves of Fig. 4.

When the light stimulus is barely visible to the eye after 7 to
20 minutes stay in the dark (one of the observers remained 28
minutes before he could see the light), the refractory period
decreases as the dark adaptation goes on.　When the dark adapta-
tion is complete or nearly complete the stimulus may be continu-
ously recognized, whereas in the beginning of the dark adaptation
process as long as 40 seconds may elapse between stimuli before
the second stimulus of the same intensity will bring about a
visual response.

This relation between the amount of dark adaptation and the
refractory period has a definite bearing on the increase in sensi-
tivity of the visual mechanism.　As the dark adaptation goes on
the visual mechanism becomes more and more sensitive, finally
reaching its maximum sensitivity in 20 to 50 minutes.　Therefore
the intensity must be progressively lowered in order to obtain
the threshold at various levels of dark adaptation.

When the intensity is held constant, barely visible to the eye at the ten-minute dark adaptation level, and a time of 40 seconds is required between successive stimuli; then, if dark adaptation has gone on 20 minutes and a stimulus of the same intensity is

TABLE III. *The relation between dark adaptation and the refractory period with the intensity constant*

Dark Adaptation—Minutes	A	B	C	F	G	H	I	K	L
			REFRACTORY	PERIOD—SECONDS					
7							40		
8			25		30		30		
9			16				26		
10			15		23		23	15	
11			12		23		15	12	
12		40		25			14	12	
13			12	15	19		15	11	
14		25	6	10	20			9	
15			6	9			17	6	
16		17	9	5	17			4	25
17			8	10			14	3	18
18			8	7			10	4	17
19			9	5	13		7	3	17
20	25	17		3			6		11
21			9	1	9		4		8
22			5	1	7		2	2	7
23		14	6				1		5
24	25		4				1	2	6
25			3		5				4
26			2						2
27	21	20	1		4				1
28						35			
29	15								
30					2				
31						25			
32	10								
33		19							
34						18			
35	10	11							
36	7				9				
37		9			7				
38	8				6				
39		6			9				
40									
41	7				6				
42		2			3				
43	9				1				
44	7	1			1				
45									
46	8								
47									
48	6								
49	4								
50	2								
51	2								

given we find that the time required between stimuli has decreased to one half or more of its initial value. Then as dark adaptation goes on still further a point is reached when the same intensity can be seen continuously.

The most of the curves in figure 4 show a rapid initial decrease in the refractory period, then a middle period of minor fluctuation of increase and decrease, finally a rather rapid decrease until the stimulus is seen continuously when it is allowed to remain on. Again it appears that the refractory period as well as the threshold is a function of the intensity of the stimulus and the state of light and dark adaptation of the eye.

Summary

In summing up the results we find that there exists a rather definite relationship among the three variables, dark adaptation, the intensity of the stimulus and a visual phenomenon similar to refractory phase in the spinal reflexes. But refractory period in vision is a great deal more complex, and more difficult to bring under accurate observation than refractory phase in spinal reflexes.

The results of the first experiment showed that the more intense the stimulus when dark adaptation is relatively constant, the shorter the refractory period; and, the less intense the stimulus the longer the refractory period. The one factor seems to vary inversely as the other.

The results of the second experiment showed that the longer the dark adaptation up to its maximum the more sensitive the visual mechanism becomes. That is, the longer dark adaptation proceeds the more the threshold decreases. Therefore the intensity threshold appears to vary inversely as the amount of dark adaptation up to its maximum. This fact has been brought out by previous investigators.

Dark adaptation is carried on by the changes in at least three functions of the eye, the pupillary adaptation (5 minutes), foveal adaptation (10 minutes), and peripheral retinal adaptation (19 to 50 minutes). Other factors of importance, but less under

experimental control, such as the nerve links leading to and from the cortex, the cortical receptive mechanism itself, and the translation of these impulses into conscious recognition, elaboration and association may play the larger part in controlling this phenomenon.

The third experiment showed that as dark adaptation goes on the refractory period becomes progressively shorter when the intensity remains constant. This has a definite bearing on the increase in sensitivity of the visual mechanism, for when the eye reaches a certain level in adaptation the constant light intensity has an intensity value far above the threshold of the receptor at that level; therefore the same relation exists here as the relation between the intensity of the stimulus and the refractory period when dark adaptation is relatively constant. It seems safe to infer that at each level or successive levels of dark adaptation, the relation between the intensity and the refractory period is one of inverse ratio. Also that the change in the threshold, and the phenomenon similar to refractory phase is modified by the state of light and dark adaptation of the eye, this in turn is probably a nervous function.

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THE DIAGNOSIS OF CHARACTER TYPES BY VISUAL AND AUDITORY THRESHOLDS

By Roland C. Travis

Method; qualitative treatment of data; statistical treatment of the data; conclusions; bibliography.

The field of mental disease offers valuable opportunities and material for experimentation toward a better understanding of the normal mind. A present need that scientific experimentation must meet is in the development of technique and methods whereby character types, character anomalies, and character trends may be accurately diagnosed with the aim of a more accurate prognosis. Workers in the fields of psychiatry and psychopathology have developed rather accurate methods of differential diagnosis between the mental diseases; but such methods are far from the desired end at the present time. Especially is this true in the so-called functional diseases. There are several syndromes that are common to several nervous and mental diseases, *e.g.*, the catatonic; and one psychosis may present certain transient symptoms which are identical with those of another and yet the two diseases may have quite a different trend and prognosis. This intermingling of symptoms makes clinical diagnosis very difficult. A correct prognosis is the cherished aim of the psychiatrist, and a correct diagnosis is the first step in that direction. Any new light that may be thrown upon the problem by way of actual experiment ought to be welcomed indeed by the diagnostician.

This experimental study subjected to a certain type of measurement two groups of abnormal individuals, the schizophrenic[1] group and the psychoneurotic.[2] The results obtained from 10

[1] Schizophrenia is Bleuler's term for simple, hebephrenic, catatonic and paranoid dementia precox.

[2] Psychoneurosis is a general term for hysteria, neurasthenia, psychasthenia and anxiety neurosis as used by May and others.

normal individuals and 12 stutterers will be included for comparison. It has been shown by many investigators that there is a contrast between these two types of abnormal individuals. That is, the general behavior of the schizophrenic is characterized by negativism, restriction of reactions, seclusiveness, emotional and mental deterioration and an introverted viewpoint; while the behavior of the psychoneurotic is characterized by suggestibility, expansion of reactions, overtness, and a correspondence between emotions, thoughts, acts and external conditions. This dual classification may be applied to normal individuals as well, the one type seclusive and introvertive, the other overt and extravertive (1).

The psychoneuroses are more common among the suggestible extravertive type, and schizophrenia is more common among the seclusive introverted type of individuals. There is no definite line distinguishing these two groups of mental disease, rather there is a shading off between the two, and many times the diagnostician is confronted with the problem of dementia precox symptoms in the hysteric and hysterical symptoms in the case of the dementia precox. However, at the extremes many of the symptoms are quite opposite.

Schizophrenia is the most common, comprising about 14 per cent to 30 per cent according to *Diefendorf* (2), 10 per cent according to *Kraepelin* (3), or 23 per cent to 39 per cent according to *Bleuler* (4), of all admissions to institutions. It is a disease of early life, more than 30 to 60 per cent of cases appearing before the 25th year. Acute diseases act as exciting causes in a small percentage of cases. Some cases present peculiar mental behavior from youth up, such as, seclusiveness, precocious piety, impulsive actions and great susceptibility to alcohol. Up to date no consistent pathological changes have been found in this disease. The major symptoms of this disease are mental and emotional deterioration. External impressions are usually correctly perceived, though they may be more or less distorted by hallucinations. Consciousness is usually clear, but there may be clouding in certain clinical states. Voluntary attention is im-

paired, and the controlling force of interest is lacking. There is a progressive impairment of memory from the onset of the disease. In early stages the patient's thought shows incoherence and looseness with a progressive defect in judgment. In the deterioration of the emotional life there is usually an early indifference and a splitting between the emotions and responses, which calls attention to the approaching disease. The disturbances of conduct are neglect of duties, indifference and inability to control impulsive actions. In general this represents the classical description of this disease, and closely follows Bleuler and Kraepelin. The prognosis of schizophrenia is very unfavorable, as most cases terminate in decided mental deterioration.

The psychoneuroses which include hysteria, neurasthenia, psychasthenia and anxiety neurosis are most commonly found among the extraverted individuals. This disease comprises about 2 per cent of all admissions to institutions. *May* (5) asserts that clinically the hysterical type has episodic mental attacks in form of delirium, stupor, dream or twilight states during which repressed wishes, mental conflicts or emotional experiences detached from ordinary consciousness break through and temporarily dominate the mind, and that the attack is followed by partial or complete amnesia. This same author states further that various physical disturbances (sensory and motor) occur in hysteria, and these represent a conversion of the effect of the repressed disturbing complexes into bodily symptoms or according to another formulation, there is a dissociation of consciousness relating to some physical function. Psychasthenia is characterized by phobias, obsessions, morbid doubts and impulsions, feelings of insufficiency, nervous tension and anxiety. Episodes of marked depression and agitation may occur. There is no disturbance of consciousness nor amnesia such as takes place in hysteria. Neurasthenia has as its major symptoms physical and mental fatiguability and irritability, hyperesthesias and paresthesias, hypochondriasis and varying degrees of depression. In anxiety neurosis morbid fear or anxiety is the most prominent feature. There is also nervous irritability, anxious expectation

and dread, and cardiac and vasomotor disturbances accompany the fears.

According to *Janet* (6), a valuable contributor to the study of hysteria, the disease " is a form of mental depression characterized by the retraction of the field of personal consciousness and a tendency to the dissociation and emancipation of the systems of ideas and functions that constitute personality." This definition is based upon the phenomena of somnambulism, fugues, amnesias, anesthesias, hyperesthesias, tics, choreas, hysterical blindness and the double personalities that occur in the hysterical. The psychoneurotic is usually very suggestible and can be hypnotized. The differential diagnosis between the psychoneuroses and the schizophrenoses is often very difficult because of the overlapping of symptoms of a transitory nature. The prognosis is usually much better for the psychoneuroses than for the schizophrenoses.

A historical survey of the reports of experts in the field on the differential diagnosis between schizophrenia and hysteria has been given by a previous investigator (7) in an experimental study on the measurement of suggestibility and negativism by changes in the auditory threshold during reverie. This author concludes " that the lowering or raising of the threshold during crystal gazing is a function of suggestibility or of negativism, as demonstrated by the desire to enter into the abstraction on the part of those whose thresholds go down and the resistance to the abstraction on the part of those whose thresholds go up." In a more recent paper (8) the same author found that all of 22 psychoneurotics showed a lowering of the auditory threshold during crystal gazing, and that 21 of 24 dementia precox cases showed a raising.

The diagnosis of each patient used in this study was that of the staff of the State Psychopathic Hospital. The author wishes to acknowledge his gratitude to Dr. S. T. Orton, Director of the Hospital, for his permission to work with the patients, also for his coöperation in the progress of the study.

Method

The apparatus used in the visual test has been described in a previous paper (9). The experimental setting was identical with that recorded in that paper except that a phonograph was employed to bring about a state of reverie comparable to that produced by crystal gazing in the auditory method, which will be described later.

The subjects in this experiment were allowed at least 20 minutes dark adaptation before the experiment began. The threshold was accurately determined after complete dark adaptation, before, during and after the reverie period. The absolute threshold was not used in this study because of the long interval required between stimuli to bring out a response to a second stimulus (as long as 120 seconds). The shorter interval of 30 seconds, controlled by an electric clock, was found to be more satisfactory. The previous paper (9) brought out the relation between dark adaptation, intensity, and the refractory period. The reader is referred to this paper for details.

When the subject was dark adapted he placed his head in the proper place in the headrest and looked steadily at the fixation light a few minutes before the experiment began. The instructions to the subject before the reverie period were as follows: " Keep your eyes fixed steadily on the small red light which will remain on continuously. A larger white light will appear periodically just below the red light, and when you see the white light, press on the key under your finger. This light will get dimmer and dimmer, but every time you see the light press on the key." The instructions had to be explained a little more fully with some of the patients. After the instructions were given the electric clock which presented the stimulus every 30 seconds with a duration of three seconds was turned on. The threshold was determined as follows (see case 1 in Table I). The diaphragm pointer was set at 15, and the subject responded to this intensity; it was then set at 14 and a response was elicited, then at 10 and no response was made, then intensities 11, 12 and 13 were given in order and no response was made, but at 14 the response was

elicited as before. When the subject responded three times to the intensity 14 and failed to respond to 13, 14 was taken as the subject's threshold for that period. Each subject was tested twice and some three times by both auditory and visual methods.

The instructions for the reverie period in the visual test were as follows: " I will now turn on the phonograph and play some music ('Annie Laurie' sung by McCormack). Relax completely and forget all present surroundings and just let your mind
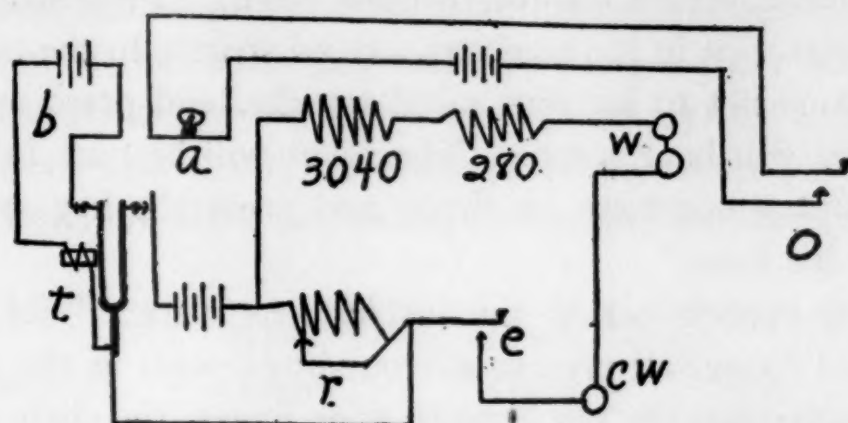

FIG. 1. Schematic drawing of auditory apparatus: (t) is electric tuning fork driven by circuit (b); (r) is resistance box which controls intensity of tone; (e) is experimenter's key; (cw) is control watch-case receiver; (w) is observer's receiver; (o) is observer's key; and (a) is response light.

wander where it will as you listen to the music. Keep your gaze on the red light. When the large white light comes on, press on the key. Don't watch particularly for the light to come on, but when you see it come on, just press on the key. Look steadily at the red light, listen to the music, and let your mind wander where it will." The threshold was determined after the phonograph had been running one minute. The same instructions were given after the reverie period as before the reverie period; and the threshold was again determined as a check on the first determination. There was usually some difference between the threshold before and after reverie, but in almost every case a greater difference was found between the threshold value during reverie and that before and after reverie.

The experimental set-up for the auditory method was similar to that used by a previous investigator (7) with the exception of several modifications. An electric tuning fork was substituted

for the tone generator, a light for the buzzer, a control receiver was added to the circuit, and Edison-Lelande wet cells were used instead of the storage battery. The accompanying diagram gives the scheme of the apparatus. The same instructions to the observer were used here as in the previous investigation, before the reverie period, and in bringing about a state of reverie. The crystal can be eliminated in bringing about a state of reverie, although its use facilitates a day-dreaming condition. Before the day-dreaming period the instructions were: " Presently you will hear a short tone in the receivers, attend strictly to the tones, take special pains not to let your mind wander, and press on the key every time you hear a tone. The tones will become fainter and fainter, but concentrate on them, and press the key every time you hear the tone."

For the reverie period the instructions were: " Relax completely and forget all present surroundings, such as the receivers against your ears, the key beneath your finger, the chair in which you are sitting, and the table on which your arm is resting. Just day-dream and build air castles, letting your mind wander where it will. Do not particularly listen for the tones you have been hearing. Do not however resist them. Think that if they come your finger will press the key. Do not be afraid to lose yourself in reverie as you will not be disturbed for quite a long time."

Each observer was tested by both the visual and auditory tests. This gave a very good means of comparing these two major sense fields as to the functional change in the threshold under the conditions of reverie. It was attempted to get the two methods as closely comparable as possible in order to ascertain the nature of the correlation between the two.

There is some question as to whether the music and instructions in the visual test brought about a state similar to the reverie period in the auditory test. It might be stated here that in every abnormal individual tested the music had a pleasing effect, and facilitated in bringing about a state of reverie or abstraction. The verbal reports of those whose thresholds went down during reverie indicated that the light appeared brighter, although it

was at a lower intensity. There was a general indication in the reports of those whose thresholds went up during reverie that the light appeared less intense. The verbal reports and the overt responses indicated that the two methods were quite comparable qualitatively.

Qualitative Treatment of Data

Tables I, II, III, and IV give the scores on both the auditory and visual tests for all observers of this experiment. Table V is a summary of the other four tables. Table I gives both the auditory and visual threshold scores for the periods before, during and after reverie for the schizophrenics. The auditory scores are in terms of ohms resistance, the smaller numbers representing

TABLE I. *Schizophrenics. Visual and auditory thresholds for the periods before, during, and after reverie*

Case No.	Before		During		After		Adapt.
	Aud.	Vis.	Aud.	Vis.	Aud.	Vis.	(min.)
1........	10	14	18	20	11	13	40
2........	48	21	73	27	52	19	40
3........	35	14	47	11	40	13	45
4........	26	8	58	14	32	7	40
5........	30	5	70	6	35	2	30
6........	22	4	24	5	21	3	20
7........	9	2	12	3	8	2	30
8........	19	5	22	10	15	7	30
9........	2	20	1	10	2	14	45
10........	65	24	70	28	50	23	60
11........	48	18	53	18	40	20	30
12........	35	16	35	18	35	15	45
13........	35	8	75	11	50	8	25
14........	22	15	29	17	15	10	40
15........	18	8	20	4	15	7	35
16........	12	4	14	5	10	3	35
17........	45	25	48	15	38	25	35
18........	65	15	80	8	65	20	45
19........	23	18	42	28	10	20	60
20........	12	18	19	25	14	19	35

The auditory scores are in terms of ohms resistance, the smaller numbers represent lower thresholds. The visual scores are in terms of steps on the scale of the iris diaphragm, the smaller numbers represent lower thresholds.

The specific types of schizophrenic diagnoses and their frequencies are as follows:

6 simple dementia precox
6 hebephrenic dementia precox
6 paranoid dementia precox
1 dementia precox schizophasia
1 dementia precox phantastica

the lower thresholds. The visual scores are given in steps on the scale of the iris diaphragm, the smaller numbers representing lower thresholds. The scores in Tables II, III and IV are made up in a similar manner. The method of the determination of each individual threshold has already been described.

The amount of time (in minutes) required for complete dark adaptation is given in each case in the last column. These numbers represent approximate determinations. Each subject was completely dark adapted before his threshold was determined. Previous investigations (10) have shown that little or no dark adaptation goes on after 45 to 60 minutes in the dark. Most of the subjects were in the dark room between 60 and 70 minutes, and some as long as 90 minutes. The thresholds of none of them lowered after 60 minutes in the dark. In the case of the stutterers each subject was given 40 minutes adaptation before the experi-

TABLE II. *Psychoneurotics. Visual and auditory thresholds for the periods before, during, and after reverie*

Case No.	Before		During		After		Adapt.
	Aud.	Vis.	Aud.	Vis.	Aud.	Vis.	(min.)
1........	25	28	18	15	24	25	25
2........	28	7	20	2	25	5	35
3........	16	27	13	24	14	27	45
4........	40	8	10	4	15	8	40
5........	48	28	33	25	35	28	35
6........	45	28	40	15	50	25	30
7........	50	15	15	7	25	13	30
8........	50	28	10	15	25	28	35
9........	50	8	28	6	48	15	30
10........	21	12	13	14	17	11	45
11........	28	18	20	10	26	20	40
12........	18	8	12	4	17	7	35
13........	35	26	32	20	36	28	40
14........	48	10	30	6	44	12	30
15........	18	10	15	5	18	5	40
16........	50	17	20	8	20	10	40
17........	48	28	47	15	48	20	35
18........	40	20	25	10	35	28	40
19........	20	25	13	28	20	15	35
20........	50	28	10	15	25	28	35

The specific types of psychoneurotic diagnoses and their frequencies are as follows:

   11 hysteria
   1 psychasthenia
   3 neurasthenia
   4 psychoneurosis unspecified
   1 psychoneurotic or manic-depressive type

ment began and thus in this group the time of dark adaptation was not determined.

A qualitative analysis of the first four tables will now be given. From Table I, it will be seen that 13 of 20 schizophrenics showed a raised auditory and visual threshold. Eighteen of the 20 cases showed a raised auditory threshold, and 14 of the 20 a raised visual threshold (Table V). Four of the 20 cases showed a raised auditory threshold and a lowered visual threshold. One of the 20 cases showed a lowered threshold on both tests. The visual scores of one case, No. 11, and the auditory of another, No. 12, could not be interpreted as either lowered or raised. The most persistent change in the threshold is a raised threshold in the case of the schizophrenics and a lowered threshold in the case of the psychoneurotics during reverie over that of the periods before and after reverie. There is a high correlation (18 of 20) between a raised auditory threshold and the schizophrenic type of individual. There is also a rather high correlation (14 of 20) between a raised visual threshold and the schizophrenic type; but the correlation is not so great as in the auditory test.

An analysis of Table II will show that 16 of 20 psychoneurotics showed a lowered threshold on both auditory and visual tests during reverie. That 17 of 20 (Table V) showed a lowered visual threshold and 19 of 20 a lowered auditory threshold. Two of the 20 cases showed a raised threshold on the visual test during reverie. One visual threshold could not be interpreted as either lowered or raised. Again, the auditory method shows a

TABLE III. *Normals. Visual and auditory thresholds for the periods before, during, and after reverie*

Case No.	Before		During		After		Adapt.
	Aud.	Vis.	Aud.	Vis.	Aud.	Vis.	(min.)
1........	35	28	25	18	30	18	45
2........	56	13	61	15	40	13	40
3........	33	3	25	3	33	3	30
4........	18	5	19	8	18	5	25
5........	15	15	37	18	15	15	45
6........	16	5	24	10	17	5	28
7........	63	10	61	5	68	8	35
8........	25	10	21	6	24	8	30
9........	36	20	34	18	35	19	25
10........	37	10	33	6	35	9	35

higher correlation between a lowered threshold on the two tests'
and the psychoneurotic type of individual. There is a high cor-
relation (19 of 20) between the diagnosis of psychoneurosis and
a lowered auditory threshold during reverie. There is also a high
correlation between the diagnosis psychoneurosis and a lowered
visual threshold during reverie (17 of 20).

In Table III, the normals, 4 showed a raised threshold on both
tests, and 4 a lowered threshold on both tests, and there were 2
doubtful cases. It will be seen that there is very little difference
between the data from the normals and that from the abnormals.
The thresholds of the stutterers as shown in Table IV show a
very wide divergence of results. Three cases show a raised
threshold on both tests, and 2 cases a lowered threshold on both
tests. There are 4 doubtful cases, 1 case with lowered auditory
threshold and raised visual threshold, and 2 cases with a raised
auditory threshold and a lowered visual threshold. The data on
the stutterers show that there is no definite type of reaction to the
test by this group.

In the case of the schizophrenic individual a much stronger
stimulus must be given during reverie as compared with before
and after reverie in order to bring about a response; but in the
case of the psychoneurotic a weaker stimulus will bring about a
response during reverie. Both the visual reports and the spon-
taneous responses of these two types of individuals would lead
one to believe that in the case of the psychoneurotic there is a

TABLE IV. *Stutterers. Visual and auditory thresholds for the periods
before, during, and after reverie*

Case No.	Before		During		After		Adapt.
	Aud.	Vis.	Aud.	Vis.	Aud.	Vis.	(min.)
1........	47	3	70	4	50	3	40
2........	18	10	15	5	18	15	40
3........	50	15	75	9	47	5	40
4........	50	17	20	8	20	10	40
5........	15	5	19	25	10	15	40
6........	47	4	65	3	35	6	40
7........	35	12	60	4	40	7	40
8........	15	12	12	5	10	20	40
9........	40	20	25	10	25	28	40
10........	13	8	15	20	11	10	40
11........	48	28	47	15	48	20	40
12........	20	25	13	28	20	15	40

fuuctional lowering of the threshold or a functional increase in the sensitivity of these two major sense fields during reverie; whereas in the case of the schizophrenic there is a functional decrease in the sensitivity.

The lowering of the threshold in the case of the psychoneurotics and raising in case of the schizophrenics seems to be brought

TABLE V. *Summary of Tables I, II, III and IV*

	A	B	C	D	E	F
Psychoneurotics ...	17	2	19		2	20
Schizophrenics	5	14	1	18	2	20
Normals	4	4	6	4	2	10
Stutterers	7	4	3	6	4	12
Totals	33	24	29	28	10	62

A—Number of cases with lowered visual threshold during reverie.
B—Number of cases with raised visual threshold during reverie.
C—Number of cases with lowered auditory threshold during reverie.
D—Number of cases with raised auditory threshold during reverie.
E—Number of cases where one threshold could not be easily interpreted as either raised or lowered.
F—Total number of cases of each kind.

about by a change in mental set, attitude, or behavior pattern from the periods before and after to the reverie period due to the nature of the instructions given. In other words, the change in the threshold is a function of the particular individual's reactions to the instructions. Neurologically this particular type of opposed reactions is attributable to central changes and not to peripheral physiological changes in the receptor itself. *Sherrington* (11) has shown that the phenomena of inhibition, summation, greater variability of threshold values, and interference are referable to central factors and not to peripheral structures.

Statistical Treatment of the Data

Tables I and II may be treated in such a manner that the reliability of the scores from the two tests can be easily obtained. If we take the arithmetic mean, the standard deviation, and the probable error of the mean for the auditory scores during reverie and the auditory scores after reverie, and compute the probable error of the difference, we find a reliable difference for Table I (using auditory scores) as follows:

During reverie		After reverie	
Mean	41	Mean	28
S.D.	24	S.D.	17
P.E.$_{mean}$	3.5	P.E.$_{mean}$	2.5

The formula for the probable error of the difference is:

$$P.E._{diff} = \sqrt{(P.E._m1)^2 + (P.E._m2)^2},$$

then substituting the values in the formula we get:

$$P.E._{diff} = \sqrt{(3.5)^2 + (2.5)^2} = 4.3,$$

carrying the procedure further we get:

M$_1$ 41
M$_2$ 28

$\dfrac{}{Diff = 13}$, then $\dfrac{13}{4.3} = 3$ P.E.'s or 2 chances in 100 that M$_1$ equals M$_2$.

The visual scores treated in the same way in Table I results in:

During reverie		After reverie	
Mean	15	Mean	11
S.D.	8	S.D.	7
P.E.$_{mean}$	1.1	P.E.$_{mean}$	1

$$P.E._{diff} = \sqrt{1.2 + 1} = 1.4$$

M$_1$ 15
M$_2$ 11

$\dfrac{}{Diff = 4}$, then $\dfrac{4}{1.4} = 2.8$ P.E.'s or 3 chances in 100 that M$_1$ equals M$_2$.

The auditory scores in Table II treated in the same way results in:

During reverie		After reverie	
Mean	20	Mean	27
S.D.	10	S.D.	11
P.E.$_m$	1.5	P.E.$_m$	1.6

M$_1$ 27
M$_2$ 20

$P.E._{diff} = \sqrt{2.2 + 2.5} = 2.1$, then $\dfrac{}{Diff = 7}$, then $\dfrac{7}{2.1} = 3.2$ P.E.'s or 2 chances in 100 that M$_1$ equals M$_2$.

The visual scores for Table II treated in same way results in:

During reverie		After reverie	
Mean	12	Mean	17
S.D.	7.3	S.D.	8.4
P.E.$_m$	1.1	P.E.$_m$	1.3

M$_1$ 17
M$_2$ 12

$P.E._{diff} = \sqrt{1.2 + 1.7} = 1.7$, then $\dfrac{}{Diff = 5}$, then $\dfrac{5}{1.7} = 3$ P.E.'s or 2 chances in 100 that M$_1$ equals M$_2$.

It will be seen from Figs. 2 and 3, representing the visual difference scores and the auditory difference scores respectively that the range is about the same as to the lowering and raising differences on the visual test; but the range is about 10 units greater for the raised auditory difference scores compared with the lowered difference scores.   These differences in the amount of raising and lowering of the threshold may not be of very great significance due to the small number of cases.   The two graphs go to

lowered   Difference Scores   raised
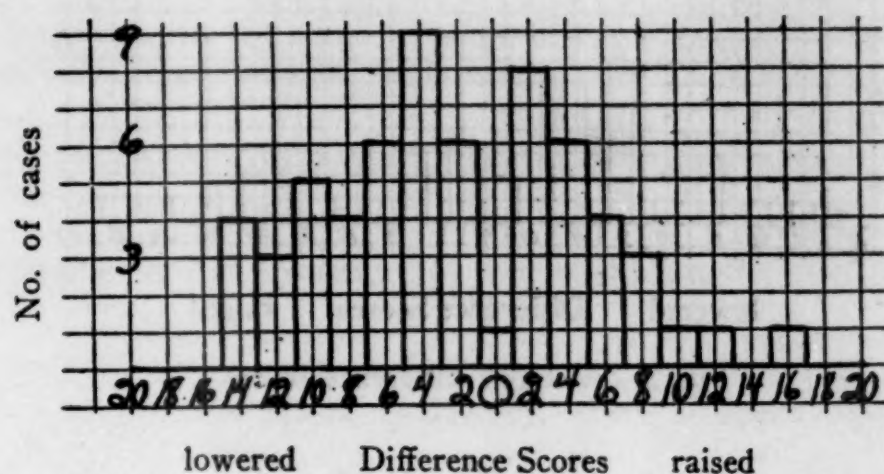
FIG. 2.   Visual difference scores

show that the data tend to fit a normal distribution curve, except that there is a sudden falling off at the zero point, and the cases are massed on either side of the zero point.

In correlating the percentage of increase in the auditory thresholds with the percentage of increase in the visual thresholds, and the percentage of decrease in the auditory thresholds with the percentage of decrease in the visual thresholds, we find the correlation coefficient to be best represented by 0.00 by the Pearson product-moment method.   That is to say, there is no correspondence between the auditory and visual tests on the same individuals as to the percentage of lowering and raising of the threshold. This lack of correlation is due to the incomparableness of the units making up the two scales.   We do not know whether the percentage increase in the auditory threshold is equal to the same percentage increase in the visual threshold, or whether a unit on

the auditory scale equals 1 or 4 or 7 units on the visual scale.
Furthermore, there seems to be no way of determining the com-
parability relationship between the quantitative decrease and
increase in the respective thresholds. We must therefore rely to
a great extent upon the qualitative meaning of the numerical
values obtained in this research; that is, whether the threshold
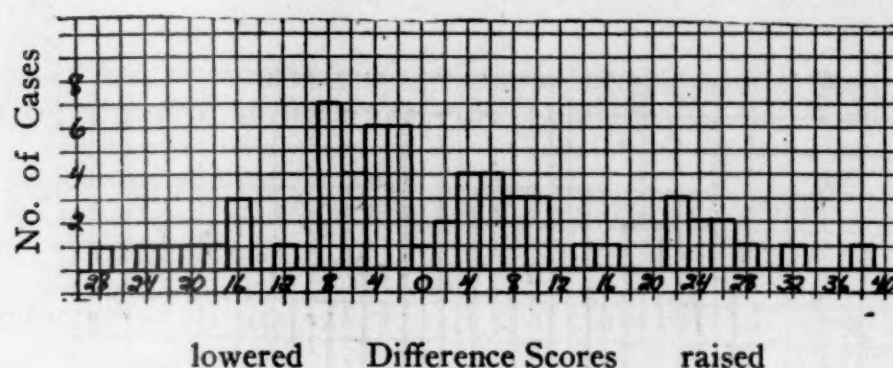has really raised or lowered during reverie; and, to determine the

lowered   Difference Scores   raised

FIG. 3. Auditory difference scores

correlation between a lowered threshold and the psychoneurotic,
or a raised threshold and the schizophrenic. This correlation can
best be expressed statistically by the use of Pearson's coefficient
of contingency (12) for broad categories.

The coefficient of contingency $(C = \sqrt{\dfrac{\phi^2}{1+\phi^2}})$ "becomes

identical with the product-moment coefficient of correlation when,
for each variable the categories are successive values of a gradu-
ated variate, and if the population is large and the number of
categories great, so that there is not a grouping error, and when
the correlation surface is normal." The data on the psycho-
neurotics and the schizophrenics may be plotted in a four-fold
table with "lowered threshold" and "raised threshold" as the
two columns; and the psychoneurotics and schizophrenics as the
two arrays, and the number of each type of cases in the proper cell.
Using the auditory scores, this four-fold table may be treated by
the coefficient of contingency method as follows:

	L	R	Totals
Psychoneurotics.	19	1	20
Schizophrenics.	1	18	19
Totals.	20	19	39

(M) Expected %	Actual %	a	a²	$\Sigma\dfrac{a^2}{M}$
26.30 —	48.72 =	—22.4	502.	19.1
24.98 —	2.56 =	22.4	502.	20.1
24.98 —	2.56 =	22.4	502.	20.1
23.73 —	46.15 =	—22.4	502.	21.2
			$X^2 =$	80.5

(M) = theoretical per cent in each cell of the table.

a = the deviation of the theoretical per cent from the actual per cent for each cell of the table.

$\Sigma\dfrac{a^2}{M}$ = sum of the deviations squared divided by the theoretical per cent.

To find ϕ in the formula for the coefficient of contingency we have:

$\phi = \dfrac{X^2}{N}$ or, = mean square contingency, where N equals total number of cases.

$C = \sqrt{\dfrac{\phi}{1 + \phi}}$ = coefficient of contingency.

The solution of the above problem would then be:

$$\phi^2 = \frac{80.5}{39} = 2.06$$

$$C = \sqrt{\frac{2.06}{3.06}} = .82$$

The correlation between a lowered auditory threshold and the psychoneurotic, and a raised auditory threshold and the schizophrenic is .82, which is a rather high correlation considering the method used.

The coefficient of contingency applied in the same way to the visual scores gives a coefficient of correlation of .72 between a lowered visual threshold and the psychoneurotics, and a raised threshold and the schizophrenics. This is also a high correlation considering the method used.

X^2 can be interpreted in terms of probability, and to eliminate the number of cells from consideration Pearson has given the two equations (Kelley, p. 264) in which " n' is the number of cells and P the probability that random sampling would lead to as large or larger divergence between theory and observation." We can enter Table XVII in the _Tables for Statisticians and Biometricians_ (13), page 31, with X^2, the value of which is 80.527 for the auditory test and 41.879314 for the visual test, the —log P values for these two values of X^2 are $\overline{16}.5188$ and $\overline{8}.3757$, respectively. Or, interpreting the values further, it would be the probability of the situation as extreme as the one observed arising as a matter of chance, as 3.302 is to 10^{16} in the case of the auditory scores, and as 2.375 is to 10^8 in the case of the visual scores. From the standpoint of probability the auditory test is about $1^1/_3$ times more reliable than the visual test in its correlation with the criterion; whereas in terms of the K values for r obtained from coefficient of alienation the predictability of the auditory scores is about 18 per cent higher than that of the visual scores.

The results obtained from three observers, each of whom observed three times on both the visual and auditory tests, will be given to indicate the variability between different trials of the tests on the same individuals.

Observer 7. Normal.

			Before	During	After
Auditory	trial	1	63	61	68
"		2	46	30	50
"		3	30	25	28
Visual	trial	1	10	5	8
"		2	18	5	8
"		3	5	3	5

Observer 8. Hysteric.

			Before	During	After
Auditory	trial	1	50	10	25
"		2	30	15	20
"		3	33	13	28
Visual	trial	1	28	15	28
"		2	20	12	18
"		3	20	10	23

Observer 13. Schizophrenic.

			Before	During	After
Auditory	trial	1................	35	75	50
"		2................	40	62	42
"		3................	30	50	28
Visual	trial	1................	8	11	8
"		2................	10	15	9
"		3................	7	12	8

It will be seen that there is a variable quantitative relationship between different trials of the tests in the amount of lowering or raising of the thresholds, but qualitatively there is a persistent occurrence of either a lowering or raising of the thresholds in repeated trials of the tests on the same individuals. That is, an individual who shows a lowering or a raising of the threshold, as the case may be, during reverie, in the first trial of the test will show a lowering or raising of his threshold in repeated trials of the tests; but the amount of lowering or raising does not necessarily remain the same from one trial to the next.

In correlating the results of the two tests with each other by the coefficient of contingency method on 60 of the cases (two cases could not be interpreted as either lowered or raised), we get a coefficient of correlation of .63 from the following four-fold table:

		Auditory		
		L	R	Totals
	L	29	8	37
Visual				
	R	3	20	23
Totals		32	28	60

$$X^2 = 40.54$$

$$\phi^2_{cor.} = \frac{40.54}{60} - \frac{1}{60} = .66$$

$$C = \sqrt{\frac{.66}{1.66}} = .63$$

In a previous paragraph the correlation between the auditory test and the criterion was found to be .82, and the correlation between the visual test and the criterion was found to be .72. Now we find that the correlation between the two tests is .63. A lower correlation between the two tests than between either test and the criterion would be expected theoretically, of course, because the errors in both tests combines the probabilities that there will be a greater divergence between the results of one test and the results of the other test, than there will be between either test and the criterion.

As was stated before, the predictability of the auditory test is about 18 per cent higher than that of the visual test, calculating from the K values for r derived from the formula for the coefficient of alienation, $(K = \sqrt{1 - r^2})$. The predictability of the obtained visual scores is 8 per cent higher than the predictability of the visual scores estimated from the obtained auditory scores. And the predictability of the obtained auditory scores is 20 per cent higher than the predictability of the auditory scores estimated from the visual scores.

Conclusions

1. From the data presented in this study the auditory and visual methods of threshold discrimination seem to be reliable means of differentiating between the clinically opposed groups, the psychoneurotic and the schizophrenic. The correlation between a lowered auditory threshold and the psychoneurotic, and a raised auditory threshold and the schizophrenic was .82 by the coefficient of contingency method. The correlation between a lowered visual threshold and the psychoneurotic and a raised visual threshold and the schizophrenic was .72 by the same method.

2. The change in auditory and visual thresholds during reverie toward an increase or decrease in sensitivity of the auditory and visual apparatus appears to be a function of the individual's reaction to the experimental conditions.

3. The abnormal individuals react to the test in about the same way that the normal individuals do.

4. There is no definite type of reaction to the tests by the stutterers.

5. The auditory test is much more simple to operate and more reliable under varying conditions than the visual test, probably because of differences inherent in the nature of the two sense organs involved. The predictability of the auditory test is 18 per cent higher than the visual test as determined from the K values for r, $(K = \sqrt{1 - r^2})$.

6. The two tests are reliable in the sense that an individual who shows a lowering or raising of his threshold during reverie

and distraction in the first trial of the test will show a lowering or raising in his threshold in repeated trials of the tests; but the amount of lowering or raising may not be the same in various trials.

7. The correlation between the two tests was found to be .63 with 60 cases.

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12. KELLEY, T. L. *Statistical Method.* New York: Macmillan, 1923, pp. 253, 265.
13. PEARSON, KARL (editor). *Tables for Statisticians and Biometricians.* Table XVII, p. 31. Values of (—log P) corresponding to given values of X^2 in a four-fold table. (Extension of Table XII for $n' = 4$, test for goodness of fit.)

AN EXPERIMENTAL STUDY OF CERTAIN TESTS AS MEASURES OF NATURAL CAPACITY AND APTITUDE FOR TYPEWRITING

BY

BENJAMIN W. ROBINSON

Previous study; present problem; description of tests used; criteria used; results; interpretation of results; future experimentation; bibliography.

Previous Study

The present study began as an attempt to discover a team of tests to be used for vocational guidance in the eighth grade for the purpose of determining natural capacity and aptitude for stenography and typewriting.

Capacity and aptitude are used in this study to designate those innate qualifications which make for success in a particular vocation. Ability, as spoken of, refers to that degree of proficiency that has been attained through training.

In an earlier study,[1] individual motor tests were included in the team of tests studied. These motor tests were *Motility as Measured by a Tapping Test* (14) and *Serial Action as Measured by Serial Reaction After Discrimination and Choice* (8). There were two reasons for the omission of these tests from the present study: (1) the fact that only a low correlation was obtained between achievement in the tests and achievement in typewriting; (2) the difficult technique of the motor tests and the time required to give individual motor tests.

On the basis of an analysis of the fundamental processes involved in stenographic procedure seventeen tests of the following types were chosen for a preliminary trial: (1) Substitution, (2) Motility, (3) Attention, (4) Recovery from interruption,

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[1] The unpublished manuscript is available in the University of Iowa library. The experiments here reported were made in 1921.

(5) Checking of misspelled words, (6) Vocabulary, (7) Grammar, (8) Completion, (9) Word-building, and (10) Form perception.

Discovery of a more satisfactory means of measuring achievement in typewriting led to a continuation of the study which was limited to the consideration of natural capacity and aptitude for typewriting.

Present Problem

From the preliminary investigation the following tests were selected for further study with a larger number of individuals in the commercial departments of Central and Northern High Schools in Detroit, Mich.: *test 0301,* checking adjacent pairs of numbers whose sum is 10; *test 0302,* checking adjacent letters forming English words; *test 1234,* writing of digits (motility); *test 0311,* Burtt's number squares; *test 0312,* cancellation of c, u, x, and z's; *test 0313,* substitution of digits for letters; Kemble's writing speed and recovery from interruption (12); Horn's checking of misspelled words; *comprehension test B1,* Iowa series 4/1/21.

The problem then resolved itself into determining whether or not the above tests measured factors essential to success in typewriting.

The tests were given during the regular class periods in typing. Since there were 9 tests, it was necessary to take 3 different periods. Descriptions of the tests and the directions for giving and scoring them are given herewith.

In giving psychological tests, either mental or motor, a very important factor is that of motivation, the supplying of the proper urge, drive, desire, or reason for the candidate to do his best. The students were therefore told that the tests to be given were similar to those used by employers of large staffs in choosing clerical help in their offices, and that it was the wish of the examiner to find out if the tests did not also measure factors essential to success in typewriting. They were asked to imagine themselves to be candidates for the position of stenographer in a large office. Whether or not they would get the position was

to be dependent upon the scores they should make in the tests. Since practically all of the students were taking shorthand and typing with the idea of entering the commercial field, this motivation was conducive to effort on their part.

Description of Tests Used

Test 0301 appeared on a single page with *test 0302* and consisted of 10 lines of 65 digits each, so arranged that occasional pairs of adjacent numbers totaled 10. Example— 67342815524610083. The directions were:

"Look at the first line which is marked 'Example.' You are to underline every adjacent pair of numbers whose sum is 10. You would underline the second and third numbers, 7 and 3, because 7 and 3 are 10; then 2 and 8, because 2 and 8 are 10; then 5 and 5, etc. Remember it is always a *pair* of numbers. Three or more adjacent numbers whose sum is 10 do not count.

Begin with the line below the example and go across one line after another in the same direction you read a book, underlining the pairs. You will have 4 minutes. If you finish before time is called, look back and see if you have left out any. Work as fast as you can without mistakes. Ready. Go."

The score was the number of pairs correctly underlined. There was no penalty for mistakes or omissions. Mistakes were rare and could usually be detected while simply counting the underlined pairs.

Test 0302 consisted of 10 lines of what appeared to be printer's pi in which were to be found combinations of letters forming English words. Example—fidoglrfpenhskwqveryjnmlztakehb. The directions were:

"Look at the first line which is marked 'Example.' You are to underline every group of two or more adjacent letters that form an English word. In the example you would underline the third, fourth and fifth letters, d-o-g, for 'dog' is a word. Then you will find p-e-n 'pen,' v-e-r-y 'very' and t-a-k-e 'take.' A single 'a' or 'I' does not count as a word. Begin with the line below the example and go across underlining the words. You will have 4 minutes. If you finish before time is called, look back and see if you have left out any. Work as fast as you can without mistakes. Ready. Go."

The score was the number of groups correctly underlined. There was no penalty for mistakes or omissions. Mistakes were rare and could usually be detected while simply counting the underlined groups.

Test 1234, a test of motility, was given on the back of the sheet containing tests 0301 and 0302. The following directions will indicate the nature of the test:

" This is to be a test of speed of action. You are to write the numbers 1, 2, 3, 4, 5, 6, 7, 8, 9, and 0 beginning when I say 'Go.' Write them as fast as you can and as many times as you can before I call 'Stop.' Having written them once start again and write them just below your first trial and so on, each trial on a separate line. You will have 1 minute. Ready. Go."

The score was the number of digits written. This was obtained by multiplying the number of full lines by 10 and then adding the number of digits in the last fraction of a line, if such occurred.

Test 0311 presented 2 squares of 9 rows and 9 columns of figures (11 to 91, inclusive), the arrangement of the numbers being, not in numerical order and dissimilar in the 2 squares except for the fact that 11, the starting point, was in the upper left corner of each square. The directions were:

" In the upper square of numbers, marked ' Part I,' are the numbers 11, 12, 13, 14, and so on up to 91, but they are scattered around so that it is hard to find them. You are to find them in order; *i.e.,* find 11, then find 12, etc. When you find 11 write 'a' after it, then find 12 and write 'b' after it, using small letters because you can write them faster. Then find 13 and write 'c' after it, and 14 and write 'd' after it, then 15 'e,' 16 'f,' and so on.

" When you get through the alphabet once, having written 'z' after one of the numbers, write 'a' after the next, then 'b' after the next and so on through the alphabet again. If you come to 'z' again, start again with 'a' after the next number. 11 is in the upper left corner of the square. You will have 8 minutes. Work as.fast as you can without mistakes, until I call 'Stop.' Ready. Go.

" Now write in the margin at the right of the square, the last number you found and the letter which you placed after it. If it was 66 and you put 'd' after it, write 66d in the margin.

" Now look at the lower square marked ' Part II.' Do exactly the same thing with this square beginning with the 11 in the upper left corner of the square. You will have 8 minutes again. Ready. Go.

" Now again write in the margin at the right of the square, the last number you found and the letter which you placed after it."

The score was the number of numbers found. The tests were checked to see that the number written in the margin was the highest number marked; 10 was then subtracted from this because the work began with 11. A key, a 11, b 12, c 13, etc., was made.

If the highest number marked corresponded and had the correct letter beside it, all that was necessary was to subtract 10. If not, the correction had to be made carefully. The mistakes were run down and if a number was omitted, the score was penalized by subtracting one from the number of numbers that were actually found. There was no penalty for a simple mistake in writing the wrong letter, for the real test was to find the numbers consecutively and the letters were merely to check this. It would probably be satisfactory merely to find the largest number marked and subtract 10 unless there were some glaring mistake. In looking back for mistakes it was found helpful to look by fives, *i.e.*, 35, 30, 25, etc. A key showing the location of the fives by line and column facilitated this.

Test 0312 utilized 10 lines of printer's pi in Roman capitals. The directions were:

"Look at the directions at the top of the page while I read them. 'In the following list of letters you are to draw a line through the letters c, u, x, and z, but not through any other letters.' That is, you are to cross out these letters wherever they occur. If you finish before time is called, look back and see if you have left any out. Work as fast as you can without mistakes. You will have 1½ minutes. Ready. Go."

The score was the number of c, u, x, and z's correctly checked.

Test 0313, substitution of digits for letters, bore at the top a key, showing for what letter each digit from 1 to 0 was to be substituted. Below this were four columns, each containing 9 four-letter combinations. The first 2 combinations had opposite them the correct digit-substitutions as a sample of the test. The directions were:

"Look at the directions for Test 0313 while I read them. 'Each figure in the above list is indicated by a letter. Discover which letter is used for each figure, then write the proper numbers in the blank spaces below. The first 2 numbers are written correctly.' That is, in the list above SXCU is equal to 7305 and TVJL is equal to 6498. You are to represent the remaining letters by the numbers given above and write them opposite the letters. Work as fast as you can without mistakes. You will have 4 minutes. Ready. Go."

The score was the number of combinations of 4 numbers, correctly given.

Kemble's writing speed and recovery from interruption test

used the text as given in *Choosing Employees by Tests* (12). The test of writing speed appeared on one side of the sheet and the test of ability to recover from interruption on the other side. The directions were:

"Look at the directions at the top of the page while I read them. 'At the signal "Go" you will be given 30 seconds to write as fast as you can from the copy below. Write in the space marked "First Trial." Ready. Go.'

"Now turn your papers over and look at the directions at the top of the page while I read them. 'At the signal "Go" you will be given 1 minute to write from the copy below, but you will be interrupted every 10 seconds to add 2 small numbers together. Put the answers to the sums opposite 1, 2, 3, etc., below. Write in the space marked "First Trial" and after putting the answer to the first addition at (1) continue to write from the copy until the second sum is given and so on until time is called. Ready. Go.'"

Numbers to be given for addition at the times indicated.

	Seconds	5	15	25	35	45	55
1st Trial....		3—5	7—3	2—4	2—7	6—1	3—8

After 1 minute say "Stop. Turn over your papers." Then repeat.

	Seconds	5	15	25	35	45	55
2d Trial....		4—7	2—5	3—2	6—4	4—5	3—3
3d Trial....		2—6	1—5	2—8	4—1	4—3	6—5

To score this test, a master copy of the text was prepared. The number of letters was marked at the end of each word to assist in checking up on the number of letters written in each trial. The last word written by the subject was taken; from the master copy the total number of letters written in each trial was then determined and the three were averaged.

The same was done for "Ability to recover from interruption." The additions were so simple that errors were disregarded. The final score was the average of the number of letters written in "Ability to recover from interruption" minus the average of the number of letters written in " Writing speed." This score gave due credit to quick recovery from interruption and penalized slow recovery.

Horn's checking of misspelled words was based on a study of 700,000 running words of business correspondence, from which the 50 most frequently misspelled words had been determined. A letter containing each of these words, misspelled, was used as the text for this test. The directions were:

"The printed matter on the other side of your paper (the paper being face down on the desk) is a letter containing the words most frequently misspelled in business correspondence. At the signal 'Go,' turn over your papers and read the letter carefully, underlining the misspelled words. Work as fast as you can and be accurate. You will have 3 minutes. Ready. Go.

"Now in the space below the letter write the correct forms of the words you have underlined as misspelled. Write these in columns beginning with the first word underlined and take them as they come in the letter. Number the words 1, 2, 3, etc. Do not under any consideration underline any more words. A test of this kind when used to select office help serves as a test of honesty. When you have finished this, write your name in the upper right corner and hold up your papers so that I may collect them. You will not be timed on this part of the test. Begin."

The score was the number of misspelled words correctly spelled, minus 2 for each correctly spelled word in the text that had been underlined as misspelled and then written incorrectly in the columns below.

Below are the correct forms of the words misspelled in the text:

1. gentlemen	18. convenient	35. certificate
2. occasion	19. college	36. possible
3. to	20. necessary	37. bulletin
4. acknowledge	21. business	38. course
5. receipt	22. opportunity	39. beginning
6. inst.	23. immediately	40. whether
7. sincerely	24. referring	41. thoroughly
8. appreciate	25. committee	42. experience
9. interest	26. feel	43. too
10. which	27. analysis	44. received
11. association	28. referred	45. truly
12. chautauqua	29. probably	46. awful
13. believe	30. mortgage	47. its
14. satisfactory	31. quite	48. attention
15. especially	32. certainly	49. convenience
16. really	33. receive	50. respectfully
17. pleasant	34. representative	

Comprehension Test B1 was arranged so that the directions and the text occupied the left-hand half of the page. On the right were 20 questions on the text which were to be answered only by direct quotation of words or phrases from the text.

The score was the number of questions correctly answered. Slight variations as to the number of words in the answer were disregarded and full credit was given.

Criteria Used

The criteria used in the preliminary study at the Iowa State Teachers' College were the best available at that time. Achievement in typing was measured by the standard *Underwood Awards Tests,* while achievement in shorthand was measured by giving the dictation at varying speeds and then having this dictation transcribed. Upon starting the study in Detroit, it was learned that *Blackstone* (1) of the typing department of Central High School had developed a measure of achievement in typing in which individual strokes were used as units. He had found the word an unsatisfactory unit, since it may contain from one to a dozen or more letters.

From the results of typewriting tests given to 3,000 pupils of typewriting in the schools of Detroit, tentative standards for speed and for accuracy have been determined. These standards were used as the basis for the criteria in this study. In these tests the difficulty of the copy was equated so that each test contains the same number of two-letter words, three-letter words, and so on, approximately similarly situated in the copy. Care was taken to have the material presented to the pupils in the same form (mimeographed sheets) because it was feared that if one test were presented in folder form with small print and another were presented in typewritten form, the difference in difficulty of reading from the copy might make the results incomparable.

A three-minute test, consisting of about 1,000 strokes, was given, and in order that the same procedure might be followed each time, the following directions were always given:

"(1) Set your machine for double spacing. (2) Set the marginal stops at 5 and 70. (3) Set the tabulator stop at 10. (4) Practice for 5 minutes on material other than the test. (5) You are not expected to finish the test, but if you do, start again on the same page. (6) Do not erase or rewrite. (7) Try to strike a steady, even pace, just as you would in copying your daily exercises."

After time was called, the copy was taken from the machine and each pupil wrote with pencil, below the test, in column form, the following: (1) Name, (2) Course, (3) Strokes wrong. (4) Strokes per minute.

Papers were then **exchanged and each error was encircled with** a pencil line. The following rule was used in deciding what constituted an error: "An error is any stroke which deviates from the copy, except that a line need not contain the same number of words as the copy. International contest rules are used with the exception that every incorrect stroke is to be counted as a separate error. According to the International contest rules, only one error shall be counted in any one word, but that is because the word is the unit of measure. In these tests, where the stroke is the unit, a word may contain as many errors as it contains strokes."

When the errors had been counted and marked, each pupil wrote below the test, " Corrected by —————," giving his name so that the teacher might check up pupils who were careless about marking errors.

A stroke was defined as any unit movement in typewriting and included the following: (1) Striking any letter, providing it did not require the use of the shift key. (2) Striking the shift key. A letter requiring the use of the shift key was counted as two strokes. (3) Striking the space bar. (4) Striking the tabulator key for making indentations at the beginning of paragraphs, etc. (5) Returning the carriage to start a new line.

The following method of counting the strokes was used: A copy of the test material was typed by the instructor, using double or triple spacing. The strokes were counted and under each word was placed the total number of strokes to that point, as in the following sample:

```
  Dear  Sir:
    5    12
            Answering  your  request,  we  recently  quoted  you  a  low  price
                  24     29        38  41        50        57  61 63  67   73
    on pianos.
    76      84
```

Explanation: In the word " Dear," there are 5 strokes, counting capital " D " as two. To the end of the word " Sir " there are 12, counting the preceding 5 and adding 1 stroke for the space between the words, 2 more for the capital " S ", 1 each for

the letters " i " and " r ", and 2 more for the colon, which requires the use of the shift key. To the end of the word "Answering" there are 24 strokes, counting the preceding 12 and adding 1 for the carriage return, 1 for the tabulator key stroke used in indenting for the paragraph, 2 more for the capital "A", and 8 more for the remaining letters.

Should it be found desirable to eliminate the need of dividing to find the number of strokes per minute in the standard three-minute test, a copy of the test could be made as in the procedure given above, except that the number under each word might be divided by 3, so that the number of strokes per minute could be determined by having the pupil note the number under the last word written. By this method our master copy would be as follows:

Dear Sir:
   2   4
            Answering your request, we recently quoted you a low price
                 8   10   13 14   17   19 20 21 22   24
   on pianos.
   25   28

The pupils having counted the errors, filed past a desk upon which the above-mentioned score sheet or master copy had been placed and noted the number under the word corresponding to the last word written on the papers held by them. This number indicated the number of strokes per minute written, as the matter of division had been taken care of in the preparation of the master copy. In case of omissions or repetitions, it was necessary to add or subtract the required number of strokes per minute, which was determined by dividing the number of strokes repeated or omitted by 3.

From the results of such tests given to the 3,000 students of typing in the Detroit schools, the following Point Score Scale was worked out. In order to become a 1,000 point typist, the pupil must write 225 or more strokes per minute with no errors, 250 or more strokes per minute with 1 error, 275 or more with 2 errors, or 300 or more with 3 errors. This places the typist in Group I as shown on the point score scale which follows. Group

II includes those writing from 175 to 224 strokes per minute
with no errors up to those writing 300 or more with 5 errors. In
this group the scores range from 900 to 1,000. Intermediate
scores are obtained by multiplying the difference between the
number of strokes per minute written and the base of Group II
in that same error column, by the constant 2.

For example, should a typist write 275 strokes per minute with
3 errors, by referring to the point score scale we find that 250
with 3 errors gives a score of 900; 275 — 250 is 25; 25 × 2 is
50, which added to 900 gives 950, the point score of a typist who
writes 275 strokes per minute with 3 errors. Similarly, the point
scores in all except Group VI are found by multiplying by the
constant indicated, when the score does not fall on a base line.

For scores below 200, the number of strokes is multiplied by
the number of fraction indicated at the base of the error column
corresponding to the number of errors made in the test. For
example, the point score for 200 strokes per minute with 9 errors
would be 4/5 of 200 or 160, since 4/5 is the constant at the base
of the 9 error column.

From a study of the test scores made in the tests given to the
3,000 students of typing, the following standards were established
as the degree of proficiency that must be attained in order to
secure a passing grade in the various courses as indicated.

Course	Strokes	Errors	Points	Reciprocals
1	96	3	195	.5128
2	160	2	455	.2198
3	201	3	647	.1546
4	221	2	735	.1361
5	250	3	771	.1297
6	300	2	888	.1126

The reciprocals above were found by dividing the point score
into 1,000. Then taking the individual point scores and multiply-
ing them by the reciprocals for their respective courses, the per
cent of efficiency (the per cent E in the tabulation of the results
that follows) of the individual is obtained. This was done to
obtain a measure that would be comparable regardless of the
grouping, since the tests were given to students of typing in

Courses 2, 3, 4, 5, and 6. This assembling of the five courses was questioned until a study of the means of the scores in the various courses was made and a comparison with the mean of the entire 255 cases made. The means of the groups, with the exception of the two smallest groups, were found to fall within the 85 to 100 array close to the entire-group mean which is 94.01. This shows sufficient homogeneity in the measures to allay any suspicion as to the statistical results being influenced materially by this grouping of the criterion scores.

Results

Having given and scored the tests according to the directions, the results were tabulated as shown in the following sample. The column headings are to be interpreted as follows:

0301	Checking adjacent pairs of numbers whose sum is 10
0302	Checking adjacent letters forming English words
1234	Motility test (writing of digits)
0311	Burtt's number squares
0312	Cancellation of C, U, X, and Z's
0313	Substitution of digits for symbols
W.S.	Kemble's writing speed and recovery from interruption
M.W.	Horn's checking of misspelled words
C.B1	Comprehension test B1, Iowa series 4/1/21
% E.	Per cent of efficiency (criterion score)

1st Hour D.N.H.S.   Samples of results

Name	0301	0302	1234	0311	0312	0313	W.S.	M.W.	C.B1	% E.
Bernstein, A.	33	73	117	52	27	20	23	29	12	89
Churchill, A.	38	46	141	41	30	28	45	33	16	95
Dancer, J.	22	63	164	48	40	26	43	29	3	60
Dunbar, F.	70	59	147	71	44	31	63	35	14	151
Dunham, H.	64	64	120	44	42	32	36	38	6	101
Friedenberg, E.	51	69	160	49	11	24	66	36	10	109
Goldberg, E.	55	58	142	32	21	23	34	28	7	177

Interpretation of Results

Pearson's Products-Moment method of correlation was used in correlating the results in the 9 tests with the % E (per cent of efficiency) used to indicate the individual's achievement in typing. The following coefficients were obtained:

Achievement in typing correlated with

1. Checking of misspelled words .... r .35, p.e. .06
2. 0311 Burtt's number finding test .... r .25, p.e. .06
3. Comprehension test B1 .... r .23, p.e. .06
4. 0313 Digit symbol substitution .... r .20, p.e. .06
5. Writing speed and recovery from interruption .... r .19, p.e. .06
6. 1234 Motility test .... r .19, p.e. .06
7. 0312 Cancellation of C, U, X, and Z's .... r .18, p.e. .06
8. 0301 Number pairs summing 10 .... r .10, p.e. .06
9. 0302 Adjacent letters forming English words .... r .07, p.e. .06

In order to determine whether or not those tests which correlated the highest with achievement in typing all measured the same factors, the 4 tests which stood the highest were intercorrelated with each other and the following results obtained:

Checking of misspelled words correlated with

1. Comprehension test B1 .... r .47, p.e. .06
2. 0311 Burtt's number squares .... r .23, p.e. .06
3. 0313 Digit symbol substitution .... r .15, p.e. .06

Comprehension test B1 correlated with

1. 0311 Burtt's number squares .... r .25, p.e. .06
2. 0313 Digit symbol substitution .... r .20, p.e. .06

0311 Burtt's number squares correlated with

1. 0313 Digit symbol substitution .... r .33, p.e. .06

Since the above tests, which correlated nearly equally with achievement in typing, show so little correlation with each other, it is safe to assume that the different tests measure different factors.

Then, to determine whether or not a composite score, showing the individual's position in the tests as a whole, correlated more highly with achievement in typing, the scores in the first 7 tests were all reduced to a score in terms of the standard deviations of the various measures. Because of their low coefficients of correlation, tests 0301 and 0302 were omitted from this compilation.

By expressing the scores in terms of the standard deviations, a method treated by *Woodworth* (16), the tests were automatically weighted. The mean score in the test was taken and the standard deviation added to get the " plus " steps in the new distribution and then subtracted to get the " minus " steps. Then

with the transmutation table thus obtained, all scores were expressed in terms of so many standard deviations, plus or minus, showing the individual's position in the frequency distribution for that test. Having treated the 7 tests in this manner, the scores thus obtained were added and averaged. This gave a score indicating the individual's position in the composite frequency distribution of the tests as a whole. These composite scores were then correlated by the Pearson Products-Moment method with achievement in typing. A correlation of r .29, p.e. .06 was found to exist. This is not so high as the correlation of the " Checking of Misspelled Words " with achievement in typing.

In order to verify the weighting of the tests, partial correlations were figured on the 4 highest tests and the criterion, after the method published by *Kelley* (11). This resulted in a correlation of r .27 between the team of tests and the criterion.

Then to be certain that the assembling of the different courses was not influencing the correlations materially, the scores obtained in the separate courses were correlated by courses with the criterion scores. The coefficients thus obtained were found to differ only .02 or .03 from those obtained when the scores in all the courses were taken together and correlated with the criterion scores. This proved the criterion as satisfactory for the advanced students as for those in Course 2.

There are two factors which might have contributed to these low correlations: either the tests were not significant measures of mental ability, or achievement in typing was not accurately measured by the method used in obtaining the criterion score in this study. Either measure is, of course, vitiated if the work is not performed with the maximum incentive. It is probable, however, that most pupils work with a fair approach to their maximum ability in taking mental tests. The test is usually brief and does not reach the point of " annoyingness " as is often done by school work. Furthermore, the pupil being unaware of, or having but a vague notion of, the real purpose of the tests, assumes that a good deal is at stake and consequently does his best. It is probable that on the other hand many students of typing do not work with the maximum incentive or do not devote sufficient time to it to

manifest their maximum ability. Any teacher of typing will heartily endorse this statement.

It must be remembered that the criterion used in this study measures a narrow though nevertheless fundamental ability essential to success in typing, *viz.*, the ability to make the coördinations necessary to the attainment of proficiency in the touch system of typing. It does not follow that these tests do not measure other traits essential to success in stenography. Who would question that ability to spell correctly is an aid to success in typing as well as in stenography? Even though it may be said that a typist does not necessarily have to be a good speller because she has the words before her, it takes much longer to copy a word which is new and not familiar than to copy one that is familiar. Ability to spell correctly may not be as essential to the copyist as to the stenographer who must rely on her memory for the spelling of the words she takes in dictation, nevertheless lack of this ability greatly increases the typist's liability to error and decreases her speed as a copyist. This no doubt accounts for the fact that the test, " Checking of Misspelled Words," correlated best with the criterion used, which involved the work of a copyist.

Stenographers are frequently required to do work of more importance than merely taking and transcribing dictation. They often hold secretarial positions which require considerable initiative and executive ability. A test of the nature of *Comprehension test B1* would no doubt measure ability analogous to that required in the receiving and answering of business correspondence. The fact that the results of this study render it inadvisable to use tests such as these to predict capacity and aptitude for typing as measured by the criterion used, does not preclude the possibility of there being value in such tests for the purpose of classifying stenographers for placement according to their several abilities.

Future Experimentation

In connection with future experimentation on this problem, special study should be made of the incentives which caused the student to take up typewriting. During the course of this study, several cases were observed where students, who were studying

typing to be able to assist financially in the support of their families, did not do well in the tests but their work in typewriting was above average. Conversely, there were students who were apparently taking typing as a side issue who did well in the tests while their grades in typewriting were below average.

To determine whether or not an individual is taking typing with a view to making it a vocation or merely to be able to get out of doing housework when through school, and then to check this information with achievement in typewriting, will no doubt result in some very interesting findings. With this knowledge it will then be possible to judge more wisely as to the value of teams of tests as measures of natural capacity and aptitude for typewriting.

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THE MEASUREMENT OF CAPACITY FOR SKILL IN STENOGRAPHY

BY

OLIVER A. OHMANN

Analysis of stenography; tests used; criteria of stenographic skill; method of experimentation; conclusions; references.

Attempts at vocational guidance during recent years have led to the study of various occupations and the development of psychological tests which purport to measure the aptitude of an individual for success in these occupations. The problem of the present study was to discover a group of tests which would measure the capacity of an individual for attaining skill in stenography.[1] The school needs such tests as a basis for educational guidance, and business would welcome such a tool as a basis for selecting stenographers. The fact that several tests of aptitude for stenography have made their appearance on the market despite their lack of statistical justification, is pathetic evidence of the eager demand for such prognostic tests, and also of the difficulty of solution of the problem. Strangely enough, the present article will not conclude by laying claims to having satisfactorily solved the problem.

Analysis of Stenography

As a first step in the investigation, a tentative analysis was made of the psychological abilities required in stenographic work. The following analysis was to serve as a guide in the selection of tests to be used:

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[1] The present study is the continuation of a research suggested by C. E. Seashore and begun by B. W. Robinson.

A. Abilities directly concerned in stenographic skill as such
  1. Rapid reaction of the hand to
     (a) visual stimuli, as in typing
     (b) auditory stimuli, as in taking dictation
  2. Accuracy of movement
  3. Kinesthetic appreciation of the spatial and temporal aspects of hand movement
  4. Helpful feeling-tone—a steady attention and interest which does not approach nervous irritation through the monotony of typing
  5. Memory span, as in taking dictation
B. Accompanying abilities indirectly concerned in stenography
  1. Linguistic ability, both oral and written, constructive and critical
  2. Knowledge of business forms, office practices and methods
  3. Skill in spelling and punctuation
  4. General fund of information, as evidenced by size of vocabulary
  5. General intelligence
C. Personal qualities *desirable*
  1. Ability to deal tactfully with people
  2. Well-poised and controlled temperament
  3. Thoroughness, as expressed by
     (a) Ability to handle detail
     (b) Ability to take and follow directions
  4. Esthetic appreciation, as expressed in cleanliness and neatness of stenographic work, and in personal appearance.

The list of personal qualities desirable is, of course, inadequate and incomplete, but nevertheless suggestive for our purpose. The fact that the analysis is not given in psychological terms throughout is an admission of the fact that much needs yet to be done in the field of mental measurement.

Tests Used

Using this inventory of the mental qualifications necessary for success in stenography as a guide, tests were devised or adapted which would measure these various factors. Without becoming involved in the theoretical considerations of whether these factors which make for stenographic skill are native or learned, or both, the aim in the selection of test material was to emphasize, as far as possible, the type of material which would call out the essential capacities and interests concerned, in the proportion that they are demanded in the actual tasks of stenography, but in such a way as to permit potential capacity to compete on an equal basis with fully developed ability. The following tests were selected:

1. *Motility test.* In addition to the usual items asking for

Name, Date, School, Grade, and Age, the blanks used for this test consisted of two sections of cross-ruled squares. The sides of the squares measured one centimeter. Each section contained twenty rows of these squares with five squares to the row. The general purpose of the tests having been explained to the pupils, the directions for the test of motility were as follows: " This is a test to see how rapidly you can make marks with your pencil. Quickness of movement of the hand is important in typing and in taking shorthand notes. When the signal ' go ' is given you are to begin at the top row of squares and make three small marks like the figure 1 in each square. Fill in as many squares as you can before the signal is given to stop. Work as rapidly as you can. Speed counts. Go!" Then at the end of one minute the signal was given to stop. The scoring of the test, which consisted of counting the total number of marks made, was facilitated by the arrangement of five squares in each row.

2. *Language test.* This test was prepared in the form of a multigraphed business letter containing many errors in grammar, spelling, punctuation, and arrangement or form. Motivation was thus stimulated by the interest that comes from an analogous situation. The directions will serve as a description of the test. " This is a test to see if you can discover errors in grammar, punctuation, and spelling, such as might be made in writing a business letter. You will be given a copy of a business letter which contains a great many mistakes of this nature. You are to mark every error you discover by placing a cross or an ' x ' over the mistake. If two errors occur in the same word, make two crosses over that word. You will be given five minutes in which to complete the test. Begin!" The score was the total number of correct crosses made, minus the number of incorrect crosses made—that is, crosses made where there were no errors.

3. *Following-directions test.* Woodworth and Wells' *Test of Hard Directions* was used to measure this factor. Three minutes were given for the completion of the test.

4. *Memory-span test.* In preliminary experiments various kinds of material were tried for measuring memory span; such

as, typical sentences from business letters, digits, and consonants. It was found that with the use of consonants the training factor and the scoring difficulties were reduced to a minimum. The consonants " w q r y t s f j h k l x z n " were used for the reason that they are dissimilar in sound and not easily confused. Consonants such as " d v b p " caused considerable misunderstanding. In giving the test the auditory stimulus was used in preference to the visual stimulus because dictation is received in auditory terms. In its final form the test material consisted of three groups of four consonants each, as " s f r j "; three groups of five consonants each; three groups of consonants of six letters each, and so on—the last three groups containing twelve consonants each, as " k z r w y j f q h t x l."

The pupils having been supplied with a blank sheet of paper, the directions were as follows: " Business men sometimes dictate a sentence or two very rapidly and then pause, while they think of something more to say. The efficient stenographer must be able to remember part of what was dictated and finish her shorthand notes during the pauses. She must be able to keep a number of words in mind until she has time to write the notes. This is a test to see how many things you can keep in mind at once. I shall dictate a group of consonants. You are to hold your pencils up while I am dictating and as soon as I have finished the group you are to write the letters in the same order in which they were dictated. Then the direction ' pencils up ' will be given again and another group will be dictated, and so on. The groups will become more difficult as we proceed. Write only one group on each line. Listen attentively! "

For completing a group of four consonants, a value of four is assigned; for a group of five, a value of five; and so on. The score will be the value of the largest group correctly reproduced. For example, if a pupil reproduced correctly two groups of six, none of the seven-letter groups, and one of the eight-letter groups, his score would be 8.

5. *Substitution test.* Pyle's *Symbol-Digit Substitution Test* was used for this purpose. The directions were: " The ability to

remember and use symbols is important in the learning of short-hand and in its use. In the next test you will be given nine symbols, each of which stands for a certain digit (or number). In the blank squares you are to write the digits which correspond to the symbols at the left. Make as many substitutions as you can until the signal is given to stop." At the end of two minutes the stop signal was given. The score was the total number of correct substitutions made.

6. *Vocabulary test.* Vasey's *Vocabulary Test* (4) was used to measure this factor. The test consists of a systematic sampling of 100 words from a standard dictionary. The directions were: " In the list of 100 words below, place a dash (—) in front of each word of which you know the meaning with enough certainty to use it in a sentence which would show that you understand the meaning. Be careful to mark every word that you know and equally careful not to mark any that you do not know. You will be tested on the meaning of some of those that you have marked." No time limit was set for this exercise. Although the size of the vocabulary may be calculated as a result of this test, the score for our purposes was simply the number of words marked with a dash.

7. *General-Intelligence test.* Intelligence quotients were arrived at by the use of the Higher Examination, Form A, of the Otis Self-Administering Test of Mental Ability.

8. *Spelling test.* Because of the importance of the ability to spell correctly, a separate test was included for this skill. The words used in the test were selected from Horn's list of the 200 words most frequently misspelled in business correspondence. The method of dictating the words was given preference over the method of checking misspelled words because the ability called for by the latter method may be quite different from that needed by the stenographer when transcribing dictation. The following directions were given: " This will be a test to see whether you can spell correctly the words which are commonly used in business correspondence. Fifty words will be dictated and you are to write them correctly on your paper. If you do

not understand the word raise your hand and it will be repeated."
The score was the total number of correctly spelled words.

9. *Handwriting test.* Aside from measuring handwriting
itself this test was included to give an index to motor control and
kinesthesis. Ayers' *Measuring Scale for Handwriting* was used
as the basis for this test. Quality rather than speed of writing
was emphasized in the directions.

10. *Character-trait rating scale.* While any comprehensive
measurement of personality traits is still an undeveloped and
difficult field, a satisfactory index to some of the more important
personal qualities of stenographers was arrived at by means of
a rating scale. A five-point graphic rating scale was developed
which included the following seven traits:

(1) Cleanliness and neatness in dress and personal appearance.
(2) Thoroughness and dependability in work.
(3) Courtesy, politeness, and tact in dealing with people.
(4) Initiative, aggressiveness, and energy in original work.
(5) Success in coöperating with associates and superiors.
(6) Excitability, nervousness, and control of emotional nature.
(7) General likeability, ease of making friends, attractiveness of personality.

These ratings were made by the teachers who had had more or
less personal contact with the students.

Criteria of Stenographic Skill

Having selected these tests to measure the various factors
probably involved in stenographic skill, the next step was to see
if they did measure this ability. At this point the perplexing
situation developed of having (1) to define what stenographic
ability is, and (2) to measure it objectively.

It is evident that while the occupation of stenographer is made
up of rather specific duties in some respects, it nevertheless varies
considerably from office to office, and even from one boss to
another within the same office. There are gradations of com-
plexity of stenographic work ranking all the way from the simple
duties of the typist who copies manuscript all day long, to the
work of the private secretary who answers correspondence and
assumes other responsibilities.

Among the criteria of stenography used by students of this problem in the past, are: teachers' marks, performance on typing tests, rankings by superiors, and various combinations of these. The search for a valid criterion was not furthered materially, even after the more or less personal and subjective factors that make for success in stenography were disregarded entirely, and only skill in the more objective functions of taking and transcribing dictation were considered. It was necessary, therefore, to devise an objective performance test in stenography which consisted of

(1) Dictating a business letter, the typing and dictation difficulty of which were known. *Dictation Transcription Test*

(2) Dictating at known rates of increasing speed—the rates of dictation being based not on the number of words per minute, but on the number of shorthand strokes required to write the words. The rate of dictation was increased in four successive steps from 90 shorthand strokes per minute to 350 strokes per minute. This corresponded to dictating the first paragraph of the letter at approximately 25 words per minute, the second at about 35 words per minute, the third at 55, and the fourth at 100 words per minute. These are the rates of dictation usually employed in the second, third, fourth, and sixth semesters respectively of a stenographic course. The fact that the word is not a satisfactory unit for measuring achievement in shorthand is clear when we see that phrases of five or six words may require no more actual shorthand strokes than the one word " retailer." For this reason the entire letter was written in shorthand characters, and the rate of dictation was based on shorthand strokes as units. The movement of the hand to the next character was also counted as a stroke. The letter was then divided into phrases which might be used as natural dictation units, and at the end of each phrase the time in seconds that should be required to dictate to that point, was indicated.

(3) Having the students take the letter in shorthand.

(4) Having the students transcribe their notes on a typewriter, record being kept of the time required for transcription.

(5) Scoring the transcriptions on the basis of (a) the amount transcribed—that is, the number of typing strokes made, (b) the quality of the transcription—that is, the number of errors made, and (c) the speed of the transcription—that is, the time required. So that the final scores on this stenographic performance test are in terms of the number of typewriting strokes per minute with the same reductions for errors as used in the *Blackstone* (1) typing tests—that is, strokes per minute times 10, divided by errors plus 10.

The following is a copy of the stenography test [1] as dictated:

Mr. Retailer: (6)
   Why is it (11) that you (13) the retailer (20) are compelled to lose (30) more good hard currency (40) through bad accounts (49) than any other man (56) in business? (61)
   Every month (2) you have to charge up (8) to bad debts (14) a score of accounts (21) that dead-beats (26) refuse to pay. (31)   Mrs. Johnson puts you off; (41) Mrs. Thompson tells you to wait, (54) and so it goes on (60) season following season. (67) You could almost (72) furnish a new store (80) with the money (83) lost by local retailers (94) through bad debts (100) in a year. (104)
   Now suppose (3) we should tell you (7) how to stop this; (12) suppose we should tell you (17) of a simple collection scheme (27) used by one retailer (30) down in Illinois (33) by which he was able (37) to make no less than thirty (42) of the hardest and slowest (48) of his customers (51) pay up (53) cent for cent, (57) all of the hundreds and hundreds of dollars (65) they owed him. (69)   Wouldn't you jump (73) at the chance to get it? (79)
   Now, then, (1) in the book described (3) by the circular enclosed, (6) you can get (7) this very collection system; (9) the simplest, (11) most successful assistance (13) of an old experienced collector; (17) a system that you can operate without help. (22)
Very truly yours, (23)

The numbers inserted in the copy at the end of each phrase indicate the number of seconds that should have elapsed before the next phrase is dictated. That is, " Mr. Retailer " is dictated and a pause is then made until the hand of the stop watch indicates that six seconds are up. Then the next phrase, " Why is it," is dictated, and so on. At the end of each paragraph of dictation the stop watch was set at zero again and the next paragraph dictated.

[1] Acknowledgment is made to E. G. Blackstone for permission to use the text of this letter. This material was chosen because the construction of the letter had received careful consideration and its typing difficulty was known.

In addition to this performance test in stenography, it was deemed advisable because of the importance of the typing function in the daily routine of stenographers, to include a standard typing performance test in our criterion. As an objective measure of the ability to typewrite, the Blackstone *Stenographic Proficiency Test, Form D* (1) was used. This test has been carefully prepared and properly standardized and forms the most valid and reliable measure of typing ability now available. Scores on this test are in terms of the number of typing strokes per minute with proper deductions for errors.

In the administration of these two criteria tests the procedure was somewhat as follows:

(1) Practice period for typing	5	minutes
(2) Typing test	3	minutes
(3) Typing practice (for relaxation)	3	minutes
(4) Stenography test, dictation	5	minutes
(5) Stenography test, transcription	10	minutes

Method of Experimentation

The tests and criteria thus selected were administered during the month of March to pupils taking the stenographic courses in Eastern and Northwestern High Schools of Detroit, Michigan. Those taking the first semester of the stenographic course were excluded from the study. The tests were thus administered to approximately 275 pupils ranging from the second to the sixth semester in the stenographic course. A number of these cases were later discarded from the actual study due to various irregularities, so that the final number of cases used was 225.

In Northwestern High School the tests were given during the regular class periods, with about 45 in each class. In Eastern High School the tests were given to the entire group at a special meeting. An hour on each of three days was needed to give all of the tests.

In order to secure proper motivation the pupils were told that the tests to be given were similar to those used by some of the large business enterprises for the selection of office help, and that an attempt was being made to find out the actual value of such

tests. The pupils were told that they were to imagine themselves applicants for stenographic positions, and that the success of their application depended upon the scores they would make on these various tests. As a result there was keen competition and rivalry.

Scores on each one of the ten tests were then correlated with scores on each of the two criteria tests, by means of the Pearson *Product-moment Method.* The following Table I, describes the results that were found, by giving the mean and standard devia-

TABLE I. *Correlations between scores of 225 pupils in typing and stenography and a number of mental tests*

Test	M.	S.D.	r with Typing	p.e. of r	r with Stenog.	p.e. r
Motility	213.8	33.22	.04	.047	—.32	.039
Language	39.5	6.92	.22	.045	.37	.038
Directions	11.4	3.70	.07	.047	.07	.044
Memory span....	48.1	16.89	—.14	.046	—.08	.003
Substitution	54.1	10.79	.04	.047	.06	.043
Vocabulary	69.4	11.58	.06	.047	.25	.042
Intell. Quotient...	111.9	10.16	—.02	.047	.26	.033
Spelling	43.7	5.60	.36	.003	.41	.037
Handwriting	60.2	10.37	.23	.044	.06	.045
Ratings*	24.4	4.03	.22	.058	.36	.051
Typing test	164.0	37.38			.31	.028
Stenog. test	47.3	25.71	.31	.028		

N = 225

* For the Ratings N = 133, since the pupils in the second semester of the course were not rated because they were not well enough known by their teachers.

tion for each test, the coefficient of correlation of each of the tests with the criteria tests, and the probable error of the coefficients of correlation.

While a casual examination of these correlation coefficients gave the impression that they were too low to be of any considerable predictive value, a further attempt was made to account for this lack of high correlation. It seemed probable that there might be at least four factors contributing to the low correlations thus obtained: (1) a faulty analysis of the skills involved in stenography, (2) an inadequate or inaccurate criterion of stenography, (3) errors of measurement of the tests used, or (4) the independence of the factors measured. This fourth possibility led to the conclusion that a correlation coefficient is not necessarily worthless as far as prediction is concerned simply because it is

low. If each of the ten tests used correlated .5 with stenographic ability, but all of the tests measured the same factor (as for example, general intelligence) then the highest predictive coefficient which could be obtained by combining these tests would be .5. But if the tests measure a number of independent factors,

TABLE II. *Zero order intercorrelations of five tests used in a study of stenography based on 225 cases*

	(1) Stenog.	(2) Motil.	(3) Lang.	(4) Vocab.	(5) I.Q.
(2) Motility	—.3297				
(3) Language	.3721	.1640			
(4) Vocabulary ..	.2515	.1972	.3656		
(5) Intell. Quot..	.2686	.1493	.4862	.2655	
(6) Spelling	.4081	.0821	.6308	.4087	.3129

each of which contributes something to success in stenography, then by combining the tests we may raise our predictive coefficient considerably.

Carrying out this idea the five tests which correlated highest with the stenographic criterion test were intercorrelated, and the method of partial and multiple correlation applied. For this work the formula and method developed by *Huffaker* (2) for the treatment of six-variable multiple correlation problems was used.

The tests which were selected for further treatment were: motility, language, vocabulary, intelligence, and spelling. Although the typing test and the personality ratings also correlated significantly with the stenographic criterion they were not considered in this further treatment since the typing test was a test of ability rather than aptitude and the ratings would have little value as predictive instruments.

TABLE III. *Coefficients of partial correlation of the first order resulting from the study of stenography based on 225 cases, and in which the variables are (1) stenography, (2) motility, (3) language, (4) vocabulary, (5) I.Q., and (6) spelling*

$$r_{12 \cdot 6} = -.3992 \qquad r_{23 \cdot 6} = .1451 \qquad r_{45 \cdot 2} = .2436$$
$$r_{13 \cdot 2} = .4576 \qquad r_{24 \cdot 6} = .1800 \qquad r_{45 \cdot 6} = .1588$$
$$r_{13 \cdot 6} = .1619 \qquad r_{25 \cdot 6} = .1306 \qquad r_{46 \cdot 2} = .4017$$
$$r_{14 \cdot 2} = .3419$$
$$r_{14 \cdot 6} = .1077 \qquad r_{34 \cdot 2} = .3446 \qquad r_{56 \cdot 2} = .3051$$
$$r_{15 \cdot 2} = .3404 \qquad r_{34 \cdot 6} = .1523$$
$$r_{15 \cdot 6} = .1625 \qquad r_{35 \cdot 2} = .4733$$
$$r_{16 \cdot 2} = .4625 \qquad r_{35 \cdot 6} = .3919$$
$$r_{36 \cdot 2} = .6216$$

The results thus obtained are given in the following tables. Tables II to VI give the zero order coefficients and the first, second, third, and fourth orders of partials. The standard deviations, regression weights, prediction formulae, and the multiple R are given in Table VII.

TABLE IV. *Coefficients of partial correlation of the second order resulting from the study of stenography based on 225 cases, and in which the variables are* (1) *stenography,* (2) *motility,* (3) *language,* (4) *vocabulary,* (5) *I.Q.,* (6) *spelling*

$$r_{12.56} = -.4298 \qquad r_{23.56} = .1029 \qquad r_{45.23} = .0916$$
$$r_{13.56} = .1082 \qquad r_{24.56} = .1628 \qquad r_{46.23} = .2550$$
$$r_{14.23} = .2207$$
$$r_{14.56} = .0841 \qquad r_{34.56} = .0992 \qquad r_{56.23} = .0149$$
$$r_{15.23} = .1488$$
$$r_{16.23} = .2557$$

TABLE V. *Coefficients of partial correlation of the third order resulting from the study of stenography based on 225 cases, and in which the variables are* (1) *stenography,* (2) *motility,* (3) *language,* (4) *vocabulary,* (5) *I.Q.,* (6) *spelling*

$$r_{12.356} = -.4459 \qquad r_{23.456} = .0884$$
$$r_{12.456} = -.4511 \qquad r_{24.356} = .1542$$
$$r_{13.456} = .1007$$
$$r_{14.356} = .0742 \qquad r_{56.234} = .0131$$
$$r_{15.234} = .1324$$
$$r_{16.234} = .2115$$

TABLE VI. *Coefficient of partial correlation of the fourth order resulting from the study of stenography based on 225 cases, and in which the variables are* (1) *stenography,* (2) *motility,* (3) *language,* (4) *vocabulary,* (5) *I.Q.,* (6) *spelling*

$$r_{12.3456} = -.4642 \qquad r_{15.2346} = .1326$$
$$r_{13.2456} = .1582 \qquad r_{16.2345} = .2117$$
$$r_{14.2356} = .1617$$

TABLE VII. *Standard deviations, regression weights, prediction formula, and multiple R based on the study of stenography involving 225 cases*

$$S.D._{1.23456} = 22.7589 \qquad b_{12.3456} = -.3644$$
$$S.D._{2.13456} = 28.9902 \qquad b_{13.2456} = .7722$$
$$S.D._{3.12456} = 4.6625 \qquad b_{14.2356} = .3802$$
$$S.D._{4.12356} = 9.6784 \qquad b_{15.2346} = .3265$$
$$S.D._{5.12346} = 9.2423 \qquad b_{16.2345} = 1.2336$$
$$S.D._{6.12345} = 3.9057$$

$$x_1 = -.3644\,x_2 + .7722\,x_3 + .3802\,x_4 + .3265\,x_5 + 1.2336\,x_6$$

$$\overline{X}_1 = -.3644\,X_2 + .7722\,X_3 + .3802\,X_4 + .3265\,X_5 + 1.2336\,X_6 + 31.7855$$
$$R_{1.23456} = .6119 \text{ p.e. } .03.$$

Conclusions

The urgent need for prognostic tests of stenography to be used in educational and vocational guidance, has focused the attention of students on repeated attempts to discover immediately the capacities involved. The investigations have demonstrated that the crux of the problem is in the establishment of a comprehensive and reliable criterion of stenography. One of the contributions of this study has been the development of a performance test in stenography which, although far from satisfactory, is a promising lead. There are several evidences to the fact that the test used in this study has considerable justification as a measure of stenographic ability.

That it measures something other than mere typing ability is shown by the low correlation between the typing test and the stenographic test. The fact that language, vocabulary, intelligence and spelling show a higher correlation with stenography than with typing indicates that these higher skills are included in the stenographic test.

The nearest approach to an absolute criterion of stenographic ability is the classification of pupils by semesters in the course. A positive correlation of .61 p.e. .027 was found between the classification of pupils by semesters and the stenographic test. This is rather high when it is remembered that the use of few class intervals on the scattergram (only semesters 2 to 6 inclusive being used) reduces the correlation coefficient materially. It is quite probable that the coefficient would rise to .7 if the groupings were not so coarse. From Table VIII below, showing the mean scores on the stenographic test by years in course and by semesters

TABLE VIII. *Mean scores on the stenographic test by years in course and semesters in course*

```
1st  year in the stenographic course—Mean =  33 N =  77
2nd  year in the stenographic course—Mean =  49 N = 130
3rd  year in the stenographic course—Mean = 114 N =  21

2nd  semester in stenographic course—Mean =  33 N =  77
3rd  semester in stenographic course—Mean =  49 N =  77
4th  semester in stenographic course—Mean =  49 N =  53
5th  semester in stenographic course—Mean =  96 N =  13
6th  semester in stenographic course—Mean = 133 N =   8
```

in course, it is evident that there is a tendency for more advanced pupils in the stenographic course to make higher scores on the criterion test used.

While teachers' marks are a rather unreliable basis of comparison, Table IX shows that in the more advanced classes where grades are usually more reliable, there is a general tendency for

TABLE IX. *Mean scores on stenography test in relation to teachers' marks in various shorthand classes*

	M. for grade 1* pupils	M. for grade 2 pupils	M. for grade 3 pupils	M. for grade 4 pupils	M. for grade 5 pupils
2nd semester	34	34	33	34	38
3rd semester	55	54	49	43	32
4th semester	40	50	44		62
5th semester	115		79		
6th semester	150		106		

* Grade 1 is the highest mark and 5 is the lowest.

pupils receiving high grades in their stenography classwork to make higher scores on the criterion test than pupils in the same class receiving lower grades. In the second semester group it is probable that the unreliability of both the stenographic test and the teachers' marks accounts for the lack of correspondence between grades and test scores.

The technique used in securing the criterion of stenographic ability is logically sound, and the results indicate that the measures are not without justification. However, it must be remembered that these tests do not measure all of the factors that may be vital to the success or failure of a stenographer. Only the actual skills involved in the taking and transcribing of dictation are measured. Stenographers are often called upon to assume other duties and responsibilities quite apart from actual stenographic skill.

In consideration of these limitations of the criterion it does not necessarily follow that because the test of general intelligence or vocabulary did not show a high correlation, these factors are not important qualifications for the stenographer. A certain amount of intelligence is required of most stenographers, even though the correlation between intelligence and the technical skill

in making the proper motor coördinations necessary for typing is low.

The criterion used in the present study is a step in the right direction, but there is need for more research along this line. If several forms of such a test of stenography were prepared and administered, reliability coefficients and other statistical evidence could be gathered to validate the technique. Improvement might also be made by analyzing the errors in the final transcript and devising some just method of weighting them. Likewise an attempt should be made to give the proper emphasis to the factors of speed and accuracy in transcription. Some students tend to give too much importance to speed at the expense of accuracy and thus receive an unfair score, while others are entirely too careful at the expense of speed. The importance of the development of a satisfactory criterion in the final solution of the central problem here treated cannot be overemphasized.

A second contribution of the present investigation lies in demonstrating that these psychological tests have considerable value as a basis for prognosis in stenography. The results shown in Table I, giving the zero-order coefficients of correlation of the various tests with the typing criterion, are substantially the same as the findings of *Robinson* (3). The inter-correlations of five of the tests reported in Table II, however, form the basis of a more fruitful approach. It is evident from this table that the tests measure fairly independent factors. The highest inter-correlation of any variable with motility, for example, is .19. More overlapping occurs in the case of the language and spelling tests. It is this independence of the variables which makes it possible to build up a multiple R as high as .61. It is quite probable that this coefficient could be raised to .7 by the lengthening of some of the tests and by introducing other refinements of the measures which were suggested as a result of the study.

By the use of the formula given in Table VII we may weight the various tests in order to secure the best estimate of a pupil's stenographic ability ($\overline{X}_1$). With a multiple R of .61 the stand-

ard error of such estimates would be reduced by about 21 per cent over what would be the case if the correlation were zero.

But as *Robinson* (3) has pointed out " vocational tests are not usually given for purposes of group selection but primarily for purposes of individual guidance. Because of this fact the distinction between ' statistical justice ' and ' individual justice ' must be carefully considered. It has been stated that, to the man who is seriously wounded in action, the fact that he had a 99 per cent chance of safety is small comfort, but the same factor is a perfectly legitimate basis at headquarters for the calculation of replacements. So extreme care must be used in the vital problem of vocational guidance, to guard the rights of the individual when making selections which are based on statistical averages."

It may be concluded then that while the battery of tests used in this study would have as much predictive value as most of the educational prognostic tests used, and more than any stenographic test now on the market, they should not be taken as entirely satisfactory, but rather as pointing the way toward a thoroughly defensible prognostic test for stenography.

It is hoped that the following suggestions may further this end:

1. Typewriting and stenography should be studied as two separate problems in order to clarify the issues.

2. The criterion test of stenography here developed should be made in several forms so that reliability coefficients and further validation might be possible.

3. The training factor should be controlled by using for testing only pupils in the fifth and sixth semesters of stenographic courses. It might be still better to use a group of stenographers in industry for such experimentation.

4. More than one performance test in stenography should be used as a basis for a criterion.

5. Some of the tests should be lengthened and adjusted in difficulty so that more ideal statistical treatment would be possible.

6. Emphasis should be given to the measurement of personality traits which make for success in stenography.

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THE RELATION BETWEEN FAULTY SPEECH AND LACK OF CERTAIN MUSICAL TALENTS

BY

LEE EDWARD TRAVIS AND MILDRED G. DAVIS

Statement of the problem; tests of specific sensory capacity; selection of cases; tables and distribution charts; tests of general ability; conclusions; references.

Statement of the Problem

The chief mechanistic difference between a speech defective [1] and an individual with normal speech is one of the adjustment of the speech organs. That is, the former is presumably not able to coördinate adequately the various parts of the speech-producing mechanism, while the latter is able to approximate, at least, an ideal adjustment of the organs of speech. There are undoubtedly various reasons why an individual may have a speech defect. Such causal factors as temperamental peculiarities, conditioned emotional responses, definite organic pathology or anomalies, faulty or inadequate training, and inherently poor muscular coördination may be listed. The emphasis in the past has been placed primarily upon the lesser motor capacity as the primary cause of most speech difficulties. In the ultimate analysis this is not only the cause, but the whole situation. That is, instead of lesser motor capacity from the standpoint of the speech organs being a cause for poor or faulty speech, it is simply a description of poor or faulty speech. Therefore, in looking for causes of speech defects, one should seek primarily for the causes of reduced voco-motor capacity. As has been indicated many factors may bear a causal relation to various types of defective speech. This study is an attempt to determine what

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[1] The term speech defective as used in this study covers the following cases: faulty articulation, lisp—lateral and central—slovenly speech, weak "s," retarded speech, nasal twang, unpleasant voice, faulty breathing, monotony of tone and monotony of volume.

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part auditory sensory elements play in certain types of speech defects.) Psychology and neurology have long held that the ear is the guiding factor in voice and that there is an intimate relationship between the auditory and motor speech cortices. Vocal expression seems to be in some sense a function of auditory processes. Thus it would appear justifiable to suppose that if an individual has a certain type of speech defect, he may also have a reduction or abnormality in the auditory field that could be detected by proper tests.

Tests of Specific Sensory Capacities

Speech corrective workers have long recognized the fact that in order to speak correctly a person should be able to hear well, and to remember differences in tones and in the volume of sounds. They have used various devices to ascertain the ability of speech corrective cases to hear differences between pitches and tones of different loudness and to remember what has been heard. Such devices have consisted of singing the scale for the speech defective and having him reproduce it; also of having him judge which of two sounds produced by the teacher is louder or softer. From these rough tests it has been noted that at least certain cases of speech defectives have been poor in reproducing what the teacher had given. These methods, though valuable for individual cases, are rough and crude measurements of the sensory capacities and give no basis whatever for comparison between normal and defective speakers. More exact measurements of certain sensory functions were therefore considered pertinent in order to ascertain if there were any sensory differences between the two groups of speakers. The *Seashore Tests for the Measurement of Musical Talent* seemed the best for this purpose as they have been well standardized and were devised to test some sensory functions which must enter into speech production. This study used three of the tests, those seeming most relevant to the problem; namely, pitch, intensity, and tonal memory. These tests are fully described by Seashore (3), and therefore will be discussed only briefly here.

The sense of pitch measures the least perceptible difference in pitch and, from the standpoint of speaking, is an index to the capacity for hearing variations in pitch. Marked lack of this capacity would result in what is called *monotony of tone.*

The sense of intensity measures the least perceptible difference in the intensity of a tone. This gives an index to the natural capacity for hearing speech in terms of loudness of the tones. A lack of this capacity in a speaker would give what is known as *monotony of volume.*

Tonal memory measured in terms of memory span for a sequence of unrelated tones is an index to the natural capacity for remembering, imaging and imagining tones soon after hearing. Poor tonal memory will result in slowness of learning various speech sounds.

The test material used consisted of a phonograph, three double disc records (pitch, intensity, and tonal memory) and test blanks. The discs were played on a standard phonograph, well regulated and in smooth running condition. In each test preliminary trials were given in which they were asked to respond orally rather than by writing. It was requested that each observer make a note of anything that might have hindered in the interpretation of the record. Each test was briefly explained and given in accordance with the standardized directions.

Selection of Cases

The tests were given to all students in the special section and to an approximately equal number in the standard and honor sections of freshman speech students of the State University of Iowa. The three divisions, special, standard, and honor, were determined by the Speech Staff not on the basis of specific sensory, motor, or intellectual capacities, but solely on the basis of ability to speak. The special section included those individuals who needed specific speech drill, such as cases of slovenly speech, oral inactivity, weak " s," lateral " s," retarded speech, nasal twang, monotony of tone, monotony of volume, articulation, unpleasant voice, and faulty breathing, and a number of individuals who

although having no specific speech fault were considered not sufficiently good speakers for the other two sections. The standard section contained students who were rated average speakers, while the honor section was made up of those students who showed superior speaking abilities. The tests were given to at least one group of twenty to thirty students, and more often to two or even three such groups at a time. Thus the groups varied from twenty to about seventy students.

The results were checked by the key. The number of mistakes in the entire record were counted and subtracted from the total number of trials. That gave the number of correct answers. Scores on the three tests were obtained on 183 students from the honor section, 153 from the standard section, and 210 from the special section. The special section was then subdivided into two groups designated as *Organic* and *Functional*,[1] the former including those cases showing organic abnormalities such as cleft palate, malocclusion, tongue-tie, etc., the latter consisting of those cases apparently having no organic anomalies and whose speech organs seemed perfectly normal.

Tables and Distribution Charts

The three sections, honor, standard, special, and the two subdivisions of the latter may be compared in regard to range of scores, mean score, distribution of scores, and standard deviation of the distribution.

Table I gives the number of cases, the mean score, the range and the standard deviation of the distribution for each group in each of the three tests.

From these tables it is evident that the three main sections—honor, standard and special—rank in the order given from the standpoint of mean score in each of the three tests and in just the reverse order when the standard deviation of the distribution in each of the three tests is considered. Nothing significant seems

[1] The Functional and Organic groups were not two sharply defined groups as no thorough physical examination was given to determine absolutely whether or not there were cases among those designated as functional who had slight organic abnormalities.

to be derived from a comparison of range of score. The functional group as compared with the organic has a lower mean score in each of the three tests and a greater standard deviation in pitch and intensity.

TABLE I

Section	Pitch			Intensity			Tonal Memory		
	No.of Cases	Mean Score	Range	S.D.of Dist.	No.of Cases	Mean Score	Range	S.D.of Dist.	No.of Cases	Mean Score	Range	S.D.of Dist.
Honor	176	77.8	53–92	9.5	150	86.9	40–98	9.6	179	73.0	32–100	15.5
Standard ...	153	76.3	55–90	10.3	153	81.3	12–97	10.4	150	69.8	38–98	17.1
Special	215	73.4	32–96	11.5	208	81.8	44–100	13.7	212	66.1	22–100	15.6
Organic	63	74.6	46–91	10.2	62	83.6	44–100	12.0	64	69.9	22–98	16.6
Functional...	126	73.4	37–96	12.0	118	82.5	40–97	13.3	125	65.4	16–100	14.3

TABLE II. *Observed differences between mean scores*

Sections [1]	Observed differences between Mean Scores		
	Pitch	Intensity	Tonal Memory
Honor—Standard	1.5 ± .76	5.6 ± .78	3.2 ± 1.2
Honor—Special	4.4 ± .72	5.0 ± .83	7.0 ± 1.1
Standard—Special	2.9 ± .79	.57* ± .85	3.7 ± 1.3
Organic—Functional	1.2 ± 1.1	1.20 ± 1.3	4.5 ± 1.6

[1] The section having the greater mean is given first.
* In this test the special section had the greater mean.

TABLE III. *Observed differences between S.D.'s of distribution*

Sections [1]	Observed differences between S.D.'s		
	Pitch	Intensity	Tonal Memory
Special—Honor	2.0 ± .50	4.1 ± .58	.01 ± .75
Special—Standard	1.2 ± .54	3.3 ± .60	1.5* ± .84
Standard—Honor	.82 ± .52	.80 ± .55	1.6 ± .86
Functional—Organic ..	1.8 ± .84	1.30 ± .93	2.3* ± 1.26

[1] The section having the greater S.D. is given first.
* Second section has greater S.D.

Tables II and III give a statement of these differences with the probable errors. There are significant differences between the mean scores of the following groups:

> *For pitch:*
> Honor *vs.* Special
> Standard *vs.* Special
> *For intensity:*
> Honor *vs.* Standard
> Honor *vs.* Special
> *For tonal memory:*
> Honor *vs.* Special

Thus there is a significant difference in all three tests between the honor and special sections which is in favor of the honor

section. In regard to pitch discrimination the standard is really superior to the special section and in regard to intensity the honor is genuinely better than the standard. There may be real differences between the mean scores of the following groups:

> *For pitch:*
>   Honor *vs.* Standard
> *For tonal memory:*
>   Honor *vs.* Standard
>   Standard *vs.* Special
>   Organic *vs.* Functional

In each comparison the first of the pair would be superior.

According to Table III there are significant differences between the standard deviations of the distributions for the following groups:

> *For pitch:*
>   Special *vs.* Honor
> *For intensity:*
>   Special *vs.* Honor
>   Special *vs.* Standard

There may be a real difference between the standard deviations of the distributions for the following groups:

> *For pitch:*
>   Special *vs.* Standard
>   Functional *vs.* Organic
> *For tonal memory:*
>   Standard *vs.* Honor

In each comparison the first of a pair would have the greater standard deviation.

Distributions are presented in Figs. 1, 2, and 3. The scale at the base runs from 50 per cent right to 100 per cent right. Each

Fig 1 - Distribution for Pitch
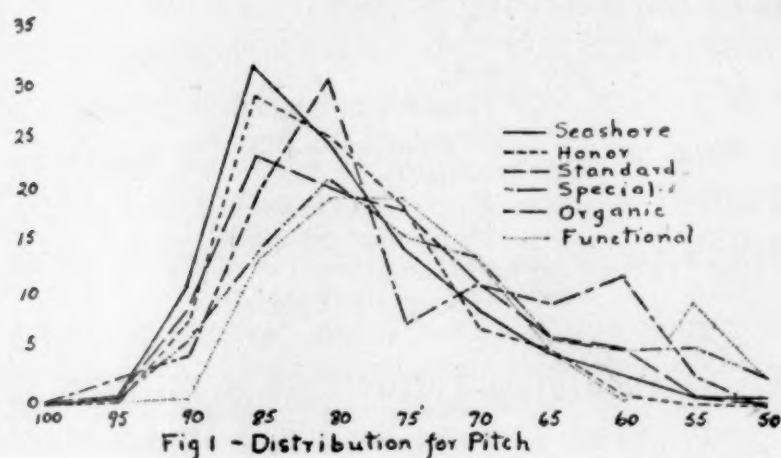
vertical line is a mid-point. The vertical scale gives the per cent of cases that occur for each per cent right. It was thought well to include for purposes of comparison Seashore's distributions (2) for adults.

Fig 2   Distribution for Intensity
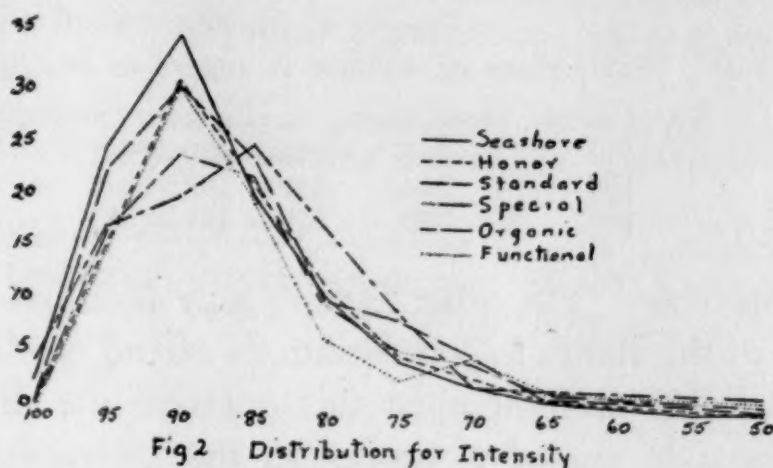
A study of the distribution charts shows in graphical form what has been indicated in the tables. The honor and standard sections are superior to the special by having in general a larger per cent of cases falling at the higher scores and a smaller per

Fig 3 - Distribution for Tonal Memory
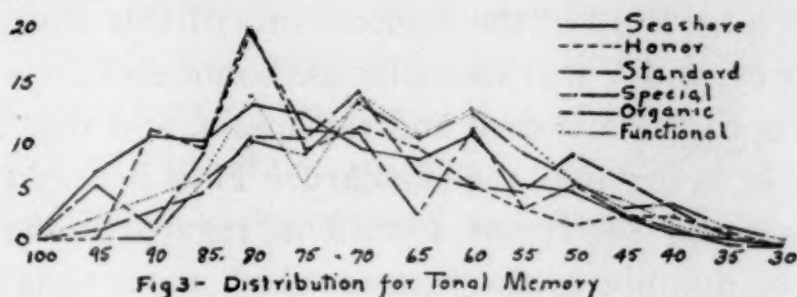
cent of the cases falling at the lower scores. Seashore's distributions compare favorably with those of the honor section. These figures indicate little difference between the organic and functional groups.

Tests of General Abilities

The data thus far show that the three Seashore Tests uncover a real difference between good speakers and those with faulty speech in regard to whatever the tests really measure. The tests were constructed to measure the least perceptile difference in pitch, the least perceptible difference in the intensity of a tone

and the memory span for a sequence of unrelated tones. Possibly these differences between the groups of speakers as were brought out by the tests are not due to differences in ability to perceive small differences in pitch or intensity or to remember a sequence of unrelated tone but are due to some other factors that the tests

TABLE IV. *Comparison of sections in regard to intelligence*

Section	No. of cases	Mean score	Range	Standard deviation
Honor	108	432	610 — 219 = 391	85
Standard	105	383	581 — 192 = 389	82
Special	150	400	579 — 144 = 435	83

may be measuring. The other factors may be those of general intelligence or the ability to concentrate, to attend, and to apply.

In order to throw light upon this question the three groups were compared in regard to scores on the University of Iowa Qualifying Examination. This examination consisted of the Thorndike Intelligence Examination, Part I, Form B, the Iowa High School Content Examination, Form B, and the Iowa Comprehension Test, Series D2. The scores on these three tests were properly weighted to give a composite score and the composite scores were considered in the comparisons of this study.

In Tables IV and V it is seen that the honor section is genuinely superior to both the standard and the special and that the special section may be better than the standard. Thus it would seem that the superiority of the honor section in regard to the Seashore Tests may be due not to the factors which those tests were supposed to measure, but to the factors measured in common by both the Seashore Tests and the University entrance examination. If this were true these two series of tests should correlate rather highly. Table VI presents the various zero order correlations.

TABLE V. *Observed differences between mean scores [1] and the probable errors of these differences*

Section	Mean scores	Observed differences	P.E. diff.	Ratio between O.D. and P.E. diff.
Honor-Special	432–400	32	7.19	4.47
Honor-Standard	432–383	49	7.73	6.37
Special-Standard	400–383	17	7.07	2.41

[1] Differences between standard deviations of distributions are not worth considering.

It is seen that there is no correlation between the three Seashore tests and the Iowa Qualifying Examination for any of the three sections.

This leads one to believe that these two series of tests are not measuring factors at all closely related. Hence it can be stated that the honor section is superior to the other two sections

TABLE VI. *Correlations between percentile ranks on Seashore tests and percentile ranks on University Qualifying Examination*

Seashore test	Honor		Standard		Special	
	Qualifying examination	No. of cases	Qualifying examination	No. of cases	Qualifying examination	No. of cases
Pitch........	—.01 ± .07	101	.02 ± .07	102	.05 ± .06	137
Intensity.....	.07 ± .06	107	.11 ± .07	90	.02 ± .06	127
Tonal memory	—.08 ± .06	107	.07 ± .07	104	.04 ± .05	146

in regard to the factors of pitch discrimination, intensity discrimination and tonal memory and whatever the qualifying examination measures, possibly general intelligence. If individuals of superior ability in speech are more intelligent than individuals with faulty speech an interesting question arises. Do intelligence and faulty speech adjustments stand in a causal relationship to each other? Speech and intelligence are undoubtedly related but probably not in a causal sequence. It may be more correct to say that speech and intelligence are two ways of looking at the same thing. *Osnato* (1) as opposed to Villiger holds this view.

Conclusions

This study seems to justify the following conclusions:

1. The *sense of pitch,* the *sense of intensity,* and *tonal memory* enter into the function of speech.

2. Certain types of speech defective cases, considered as a group, give lower scores on tests designed to measure the *sense of pitch,* the *sense of intensity,* and *tonal memory* than individuals selected in regard to their special abilities as good speakers.

3. The speech defective group from the standpoint of distribution of scores on the three Seashore tests shows a greater variability than the normal speaking groups.

4. The ranges of the various groups do not vary much. Yet there is a tendency for the special section to present the lowest scores on each of the three Seashore tests.

5. The organic group of the special section does not show the superiority over the functional group that one might anticipate.

6. The honor section is superior to the other two from the standpoint of the University of Iowa Qualifying Examination.

7. Inasmuch as there is no correlation between scores on the three Seashore tests and those of the qualifying examination, it is thought that these two series of tests measure different things and that the honor section is better in regard to both specific and general abilities.

Although the results are rather definite in regard to the differences between the honor and special sections, many factors have entered to obliterate certain other findings which a student of speech defects might expect. One thing that entered was the factor of personnel of the three sections. A great many in the special section had faulty speech because of excessive timidity, extreme bashfulness, poor environmental adjustments, and emotional instability. Surely it cannot be expected that the Seashore tests at least would give a differential indication in regard to these cases. Then, too, the standard and honor sections were not homogeneous. That is, each one of these sections contained individuals who at one time or another had been in the special section. Some had been sent from the special section to one of the other sections while others had been sent from the honor and standard sections to the special. This simply indicated that a great many of the speech defects were extremely mild. Many of those who were sent from the special section to one of the other sections were promoted on the basis of very rapid improvement.

If a study of this kind could be made on a relatively large number of definite speech defective cases of the functional type, some very clear differentiations should be discovered. Such a study ought to be of value from several points of view. (1) It should afford one basis for the prediction of success or failure in corrective speech work. Seashore (3) has quite well established the

fact that his three tests used in this study are tests of elemental capacities. Now if it is found that there is a close correspondence between certain types of speech defects and low scores on these tests, then the teacher can reasonably assume, should she receive cases of these particular types, that they will show slow if any improvement. On the other hand if a speech defective case which rates high on these various tests comes into the clinic, then it can be assumed that this particular case at least, ought to improve under proper training. (2) It ought to throw more light on the complex problem of the function of speech. (3) The speech clinic should profit by having other objective tools added to its list.

Out of studies of this nature should come others such as: (1) Comparison of the scores on the Seashore Tests of Musical Talent and some test of general intelligence between cases of rapid improvement and cases of slow or no improvement; (2) Scores from stutterers compared with scores from non-stutterers; and (3) A comparison of the scores made by the various types of lisping.

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THE BASIC FACTORS IN THE HUMAN VOICE

BY

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Preliminary psychological considerations: the vocal mechanism—its structure and function, neural aspects of voice production; the basic factors: pitch, intensity, time, timbre, volume; motor capacities; sensory capacities: pitch discrimination, intensity discrimination, auditory acuity, time discrimination, perception of rhythm, of timbre, of consonance, discrimination of kinesthetic sensations; higher cognitive powers involved in voice production: imagery, imagination, memory, intelligence; the emotions and the voice; bibliography.

This investigation is an historical and analytical study of the human voice—its nature, production, and control. The analysis of the voice is made primarily from the psychological point of view, with the five basic factors in the voice constituting the main points of departure. The physiological aspect of the voice is considered in so far as it is necessary to determine all the conditioning factors in the production of voice as a whole and in the production of any of its basic elements. Likewise the physical aspect of the voice is considered in so far as it makes clear the nature of vocal tone and some of the problems of voice production.

The psychological analysis of the human voice may be best carried out in terms of the basic factors—pitch, intensity, time, timbre, and volume—for these represent the characteristic attributes of all vocal tone. All thought, feeling, and action that may be embodied or suggested in vocal utterance is expressed or appreciated through the medium of one or more of these factors. And any scientific or practical rating of voice must be made with reference to one or more of these elements. The factors of pitch, intensity, and time are fundamental attributes of all sound, and hence they are inherent elements of vocal tone. Timbre is essentially a pitch complex, but it denotes the clang or character of a tone as the attribute of pitch itself does not do. Likewise volume [1] while it is dependent on, or correlative with, pitch,

[1] Volume is used here in the sense defined by *Seashore* (**88**, p. 165–6).

intensity, and timbre, also characterizes a vocal tone in a way that each of the three inherent factors do not.

The general plan of the study is to show, as far as possible, with reference to each one of the basic factors in the voice (1) its general nature and value from a musical standpoint, (2) how it is produced or determined, (3) what conditions may affect or modify it, and (4) an evaluation of the elements or capacities involved in its control. Such a comprehensive study involves the consideration of manifold problems many of which scientific research has not yet solved. Yet each problem will be considered as far as available scientific data permit.

This study is limited primarily to the normal, adult voice and more specifically to the singing voice. However, since song and speech use the same vocal mechanism, many of the data presented will probably be applicable also to the speaking voice.

Preliminary Physiological Considerations

The vocal mechanism: its structure and function. The physiological mechanism of the voice consists of three parts, conveniently called the bellows, vibrator, and resonator. The bellows consists of the respiratory apparatus—the trachea, bronchi, lungs, diaphragm, and the muscles of the thorax and the abdomen. The vibrator, the primary organ of phonation, consists of the larynx with its muscular attachments and the vocal cords. The resonator consists of two sets of structures: (1) the resonating cavities, which include the vestibule, pharynx (oro-pharynx and nasopharynx), buccal cavity, nasal cavities, and probably the accessory sinuses (frontal, sphenoid, ethmoid, and antra); (2) the movable structures—tongue, velum, lips, cheeks, and jaw—which vary the size and shape of the resonating cavities.

The function of each part of the vocal mechanism is aptly stated by *Kenyon* (38) in his account of the nature of vocal control. He says, " The finer control of the voice, especially for artistic purposes, is dependent on three primary factors: (1) the maintenance, by trained action of the chest musculature, of a controlled and adequate air pressure against the vocal cords;

(2) the trained coördination of the entire laryngeal musculature, extrinsic and intrinsic, to adjust the vocal cords to receive accurately and adequately the air pressure from the lungs, and (3) the accompanying adjustment of the same and related musculatures to so shape the resonance spaces that they shall give proper resonance values to the sound vibrations produced by the vocal cords. Strength of muscle, accuracy of action, trained control, all to a definite end are the needs. . . . Delicate harmony of action of the entire vocal musculature is required." Thus the three parts of the vocal mechanism comprise a functional unit, exceedingly complex, the complete control of which is essential in the artistic rendering of each vocal attribute.

Neural aspects of voice production. Refined control of the complex musculature of the vocal mechanism is made possible by the underlying neural organization. This implies not only that all parts of the bellows, vibrator, and resonator are functionally bound up with each other but also that a number of sensory mechanisms are intimately connected with the centers of motor discharge. It has been demonstrated, for example, that the innervation of the larynx is closely bound up, by both sensory and motor connections, with the innervation of the diaphragm, the ear, the muscles of the face, and the other parts of the vocal apparatus (43). This close interdependence of all the vocal parts, by means of their intricate and extensive connections, has led to the belief, now widely accepted, that instead of only one cortical area being the center of phonation, the whole cortex is more or less involved in vocal function (61).

Stability of vocal control is directly dependent on the nature of neural discharge from the motor centers. The motor cells in the brain and cord, which maintain the tetanic contraction of the vocal muscles during phonation, normally discharge at a certain rhythm and the vocal muscles contract in a similarly rhythmic manner. The rate of neural discharge may vary for each group of cells but for any particular group the rate is practically constant, even though intensity of the stimuli may vary (35, p. 44). These conditions of themselves tend to imply a stability

of muscular activity that is almost perfect. However, curves of tetanic contraction of any individual muscle show that neural stimulation, or at least its effect, varies somewhat from moment to moment. As *Howell* (35) states, " In complete tetanus the muscle seems to be in a condition of continuous uniform contraction. . . . It can be shown, however, that in reality each stimulus has its own effect, and that the chemical changes underlying the phenomena of contraction form an interrupted series corresponding, within limits, to the series of stimuli sent in " (p. 44). This condition implies with respect to any given vocal adjustment that it is never absolutely stable, that there is a continuous variation of muscular contraction during that adjustment and therefore a variation in tone. This accords with observed facts as revealed in graphic curves of speech and song, even where the variation in tone is not always noticeable to the ear. Irregularity of neural stimulation may be further increased by an increase in intensity of the stimuli even though the rate of discharge may remain unaffected. This means that a tone of strong intensity is less stable than a soft tone, a fact that is also revealed in the graphic records of speech and song.

Stability as well as accuracy of vocal control is also affected by the character of the neural stimulation that maintains muscular tonus. This stimulation determines both the readiness with which the muscles will respond and also the very nature of their response; and since it varies with fatigue, lack of nourishment, ill health, emotional status—anything that influences the vitality of the nerve centers, it has a profound influence on the whole voice—pitch, timbre, and every other factor. The extent of its effect in each case has not been determined experimentally, but it is definitely known that a close relation exists between muscular tonicity and muscular control.

These facts regarding the functioning of the physiological mechanism of the voice indicate that stability of muscular control is conditioned largely by factors inherent in the organism. This constitutes a fact of vital significance, especially in the determination of motor capacities in voice production, as will be seen later.

Though highly important, stability of muscular action is but one phase of voice control. The element of accuracy also plays a large part in the artistic control of the voice—accuracy in pitch, in time, and in all the other attributes of vocal tone. Its control seems to be dependent mainly on auditory and other capacities, the significance of which will be considered in a later section.

The Basic Factors

Pitch. Pitch is at once the essence of melody and an effective medium of musical expression. To sing in pitch is a requirement imposed on the artistic singer and its complete mastery is a cherished aim in the technique of his art. But singing in pitch is not a mere perfunctory exactness in the execution of tone. To the artist in song the variants of pitch offer an expressive outlet for his moods and sentiments; they are an effective symbol of his ideas and ideals. As color is the expressive symbol of the language of painting, so is pitch the expressive symbol of the language of music. And the would-be singer must diligently strive to let pitch fulfil its important function.

The singing of pitch includes four specific forms of singing ability: reproducing a key tone, singing intervals, singing minimal changes in pitch, and sustaining a tone at constant or artistically varied pitch.

The physiological mechanism that produces pitch consists of the vocal cords and their adjusting muscles, the intrinsic and extrinsic muscles of the larynx. The cords, however, alone are the ultimate determiners of pitch. Their frequency at any given time is the frequency of the resultant tone. And, on the basis of sex difference, the general structure of the cords seems to be the determining factor in the range of frequencies that may be produced (27). Thus, the fact that the tonal range of the male is on the average an octave below that of the female seems to be due primarily to his larger and heavier cords.[1] But as gross structure

[1] It is yet undetermined whether basses, baritones, and tenors, for example, might be classified on the basis of the structure of the cords, or even on the basis of total laryngeal structure.

of the cords merely determines the general pitch range, there must be delicate changes within that structure to produce all the desired pitches within the range. A soprano, for example, with a range from c^1 to c^3, must so effect changes in the vocal cords as to produce all the different frequencies from 256 d.v. to 1,024 d.v. These changes that must be made in the cords consist of variations in length, tension, or thickness. Owing to the interplay of these elements the ratio of any one of them to the pitch produced may be altered by slight changes in either of the other two. Thus short cords may produce the same tone as long ones if only in the shortening a corresponding lessening of tension takes place (57). Intensity is also a complicating factor. An increase in air pressure on the cords with its corresponding increase in intensity of tone will so affect the interplay of the changing elements that a complete readjustment is necessary if a constant pitch is to be maintained. *Schoen* (79) has observed that pitch always tends to rise with an increase of intensity.

While the vocal cords are the ultimate determiners of pitch, they are in turn adjusted and therefore influenced by the numerous intrinsic and extrinsic muscles of the larynx. To adjust and maintain this complex musculature at proper tension constitutes the main function of the capacities operative in pitch control.

Intensity. As a basic factor in vocal tone, intensity, like pitch, has its function in musical expression. Intensity of the subjective experience can often be expressed by a suitable intensity of tone. But no hard and fast rules goven the gradation of intensity in voice, as in the case of pitch, for its rendition permits of more spontaneous expression. No single principle can be laid down which if observed will always insure a maximum congruity between subjective motive and strength of tone. The individual singer is free to exercise his own taste and judgment in determining the most effective intensity of voice. It therefore becomes tone. But no hard and fast rules govern the gradation of intensity mechanism to adapt in the most artistic manner the strength of tone to all the fine shadings of feeling and thought.

The significance of the intensity mechanism—its function and

control—will be sufficiently revealed in the following summary of the investigations[1] of intensity production:

(1) Intensity of voice varies with the amount of sub-glottal pressure.[2] This, in turn, depends on the individual's lung capacity and on the strength of the respiratory muscles.

(2) Intensity varies with the amount of breath expended. The effectiveness of cord vibration is an important factor here; at its maximum efficiency the volume of breath expended is very small.

(3) When intensity is to be kept constant, breath expenditure varies with duration of vocal tone. This signifies that for any prolonged duration of tone there must of necessity be a constant readjustment of the vocal mechanism in order to maintain the tone at uniform loudness.

(4) Intensity varies inversely with the pitch of the tone sung, when the physiological factors (sub-glottal pressure, effectiveness of cord vibration, etc.) are constant; or, the physiological factors vary inversely with pitch when intensity remains constant. While Grützner's results do not conform to this principle, it nevertheless seems that the principle must harmonize with the established physical law, that for equal physical intensities produced at different frequencies, the amplitudes must vary inversely with their frequencies.

(5) Intensity varies with the different vowel sounds when the physiological factors are constant; or the physiological factors vary with the different vowel sounds when intensity is constant. The amount of resonance supplied each vowel is clearly a variable factor here, for in general the vowels that required the least resonance space in pronunciation registered the highest pressures and the largest volumes of breath expended. In fact, resonance is a factor in all the different intensities. Other things being equal, that tone will be the loudest that makes the best use of all available resonance space. But the resonating cavities can not function to the same degree or in the same manner for all qualities of tone. They must be continually adjusted—varied in size and shape—to suit the nature of the tone produced. They must vary not only with differences in vowel sounds but with different intensities of the same vowel.

This brief summary indicates, first, that the control of intensity implies the control of the whole vocal mechanism, particularly the bellows and resonator; and, second, that in maintaining a given intensity a readjustment of this mechanism is necessary for every variation in interval, in pitch, and in vowel sound produced.

Time. Time as a basic factor in voice is manifest in two ways: in the measured durations of tone and in the measured intervals of silence between tones. In either case it may be an expressive

[1] These investigations were made by *Cagniard-Latour* (9), *Grützner* (25), and *Roudet* (72–73). In each study, subjective intensity was measured in terms of sub-glottal pressure, or in terms of the amount of breath expenditure.

[2] The proviso "other things being equal," is to be assumed throughout this summary.

symbol in the language of music. Artistic singing requires that its time elements be appropriately adapted to the musical setting and to the nature of the concepts to be conveyed. Thus the time elements in the song of devotional fervor will differ from those of the military march; and the regard for time in the dirge will not be the same as in the song of patriotic ardor. But time, like intensity, especially in individual singing, permits and demands individual expression. The rendition of time with mechanical exactness would make of the singer more of a " musical carpenter " than an interpreter of musical thought. Yet, to be an effective measure of musical values, the factor of time must be observed with intervals of sufficient exactness in order that it may be a true medium of vocal expression.

Unlike the other basic factors of voice, time is not conditioned directly by the structure or function of the physiological mechanism, except as there is a physiological limit to the production of tones of very long duration. Time is rather a kind of limiting factor imposed upon each of the other characteristics of tone.

Timbre. Timbre distinguishes the voice from all other sounds and differentiates one voice from another. It is that element in a singer's or speaker's tone that causes it to be designated as harsh or soft, as pleasing or displeasing, as dull or vital, as musical or unmusical, as thin and hollow, or rich and full. Timbre more than pitch or any other single factor, determines the success of a singer. A lack of richness in timbre is hardly compensated for by superior attainment in the singing of pitch, intensity, or time; on the other hand, a highly accurate technique in these factors may well be sacrificed to some extent if a singer possesses those qualities of voice that give it a marked richness of tone.

Psychologically, the timbre that characterizes a given tone is determined by the number of its overtones and their relative intensities. Thus variations in the number, order (or pitch), and relative intensities of the overtones will account for all the variations in timbre in the human voice. Physically, the components or partials of a vocal tone are expressed in the form or contour of the sound wave. These sound waves can now be registered

and analyzed by the technical expert and the number and nature of the partials can be determined with a fair degree of accuracy. Important facts about vocal timbre have thus been revealed by the analyses of normal voices. For example, *Miller* (53) found eighteen partials in one analysis of the vowel *a,* pronounced as in mat, the highest partial being the twenty-fourth harmonic. Also, in the vowel *e,* as in met, he found sixteen partials, the highest being the twenty-third harmonic. And *Stumpf* (103) has recently been able to detect the thirty-sixth partial in some voices.[1]

It has also been found that the intensity of certain partials or groups of partials forms the basis of distinction between the different vowels; that is, each vowel sound is characterized by the relative prominence of certain partials. To illustrate, *Miller* (53) found that the determining partial in each of the vowel sounds as indicated in the words ma, maw, mow, and moo, had the pitches of 910, 732, 461, and 326, respectively. Other vowel sounds had two determining partials. Thus for *a,* in mat, they were 800 and 1,840; for *ee,* in meet, they were 308 and 3,100. The above figures may be considered as only approximate, for they will vary somewhat with pitch or intonation and with the manner of pronunciation. But it is now quite widely accepted that the partials which characterize a vowel are found in a fixed region of the scale. This implies that the resonance of a vowel is quite independent of the fundamental and that a vowel cannot be sounded in its pure form, at a pitch above this resonance region.

The relation between pitch and intensity among the partials is illustrated in the vowel sound of *ee,* referred to above, and similar examples may be found in certain other vowel sounds. In the case of *ee,* according to *Miller* (53), the partial of 3,100 d.v. is of less intensity than the one of 308 d.v.; but, because of its position in the array of partials, it has greater effect on the timbre of the vowel. Peculiarities of timbre may then be due quite as much to the presence or absence of partials with certain pitches as to the relative intensities among the partials. This will account

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[1] Whether the partials in a vocal tone really form a harmonic series is still a disputed question.

for differences in timbre between musical and non-musical voices; between the voices of children and those of adults; between the voices of men and those of women; although all may produce the same vowel sounds at the same pitch.

The analysis of consonant sounds has not been carried out as thoroughly or as extensively as in the case of the vowels, but it is clear that they also consist of an array of partials, the number and character of which determine the nature of consonant timbre in part. With some exceptions, the consonant sounds do not possess the musical value of vowel sounds and therefore they have a relatively subordinate place in vocal timbre.

The nature of vocal timbre is determined mainly by the vibrator and the resonator. The vibrator affects timbre through the structure of the larynx as a whole, but probably more specifically through the structure and function of the vocal cords. The importance of structure, and to some degree of function, is sufficiently indicated by the difference in men's and women's voices. It has been further observed relative to function, particularly that of the vocal cords, that as timbre varies with tonal register so does the characteristic action of the cords vary with tonal register (59).[1]

From the artistic viewpoint, the resonator is probably the most important instrument of timbre. Apart from the movable structures, like the tongue and velum, it comprises a complex array of cavities differing in accessibility, size, shape, and in the texture of their walls. Because of these differences and also because so many of the cavities function coördinately as compound resonators, the significance of each is known only in a very general way. The available data bearing on the function of the resonator in timbre production may be summarized as follows:

(1) The pharynx and buccal cavity, considered as a compound resonator, constitute the main resonance chamber for the lower partials in vocal tone.

[1] *Scripture* (81) holds that the form of the glottal closure depends on the kind of tone to be produced rather than upon its place in the tonal range, and furthermore, that timbre is determined wholly by the adjustment of the cords. This extreme emphasis on glottal action is quite out of harmony with the evidence of the importance of the resonating cavities.

These partials include the fundamental tone and all the characteristic partials of the vowel sounds (**48**).

(2) The upper cavities, including the naso-pharynx, the nasal passages, and probably the sinuses, intensify the upper partials of vocal tone. There is perhaps no clearly defined limit below which partials are intensified in the lower resonance cavity and above which they gain their resonance in the upper cavities (**48**).

(3) The sounds that are most dependent on the resonance of the upper cavities are those of m, n, and ng (**32**).

(4) The resonance value of the sinuses is very small, probably negligible. This signifies that so-called nasal resonance is produced almost wholly, if not altogether, within the nares and naso-pharynx (**50**).

(5) Nasal resonance forms an integral part of artistic vocal timbre. The proportion of such resonance that may be desired cannot yet be stated in exact terms. The tone of ideal timbre evidently requires a certain balance, in pitch and intensity, among the upper and lower partials the exact nature of which remains for experimental esthetics to determine. Nasal resonance is always present, for while the position of the velum varies with different sounds it never completely isolates the upper cavities (**49**).

(6) Production of artistic timbre requires delicate control of the tongue, velum, lips, cheeks, and jaw.

Volume. Volume is that characteristic of vocal tone which gives it the element of size or bigness. Tones may be experienced as being small and thin, on the one hand, or as large and expansive, on the other; and in each case the particular volume may be the most appropriate in creating the desired musical effect. It thus plays a rôle in musical expression peculiarly its own, although, as will be noted later, it is closely related to other factors in voice. By virtue of volume alone certain musical values are better expressed by one type of voice or tone than by another. Artistic interpretation of music seems to require a certain congruity between volume of tone and the mental experience to be expressed. But the rendition of volume does not demand the observance of rigid standards.

The term volume is used here as defined by *Seashore* (**88**, pp. 165–66). He analyzes volume into the following forms: extensity-volume (extensity being understood to be parallel with pitch), intensity-volume, timbre-volume, and duplication-volume. The last form is obviously not found in the individual singing voice. As volume of vocal tone will then vary with pitch, intensity, and timbre, it does not call for any special consideration apart from the recognition of its nature and importance. Its

production and control require no mechanism or capacities other than those required in the factors with which it correlates.

Motor Capacities

The analysis of voice into its fundamental factors makes it apparent that motor control in singing resolves itself into the control of each of the five fundamental factors. These forms of control are, however, very complex functions, and it is also an obvious fact that a high level of artistic accomplishment in each is largely the result of training and practice. The ordinary criteria for rating the trained singer are therefore not applicable to the beginner, at least as far as vocational guidance is concerned. The problem is to find other criteria the application of which will determine the degree of potential voice control before training is begun.

There are in all probability simple, elemental, or basic capacities underlying the more complex, acquired functions. If this assumption is true, then the complex forms of motor activity in voice production may be analyzed into specific motor capacities in which individual proficiency is attained early in life or at least may be attained with limited practice. With such an analysis accomplished, the development of scientific knowledge and technique with reference to the measurement and evaluation of the basic motor capacities in voice would constitute a most notable contribution to effective musical guidance and to voice rating generally. While very little has as yet been accomplished toward the realization of this worthy goal, the importance of the problem demands a consideration of some of its aspects.

Before the basic motor capacities in voice can be scientifically determined and evaluated two conditions must be met: (1) the degree of accuracy with which each vocal factor may be produced and controlled must be measured in terms of standard objective units; (2) norms must be established relative to the rendition of each of the vocal factors. Only on such unequivocal bases can one determine, by comparative or statistical method, the real value of any capacity involved in the production of voice. Practical

results may of course be obtained where these conditions have been only partially realized. Furthermore, if the rendition of song is to remain a real art where personal equations must be allowed to come to the fore, the second condition cannot be applied with the same severity to each phase of vocal control.

Only in the case of singing pitch have the two specified conditions been adequately met. Ability in pitch control can be measured in standard objective units on the tonoscope (89) and also by graphic or photographic methods and standards for pitch singing are reasonably definite. Time control has also been measured in standard units with a high degree of accuracy both in song (106) and speech (109) ; but as far as the second condition is concerned norms for the execution of time in song have not been worked out, and it is also well recognized that time relations do not always have to conform to exact specifications as in the case of pitch. In the case of intensity neither condition has yet been met and there is apparently less demand for definite standards to be adhered to in the control of intensity than in the case of time. As for timbre, while its analysis and measurement in terms of objective units has proceeded far enough to be of value in understanding the nature of vocal tone, such analyses demand as yet too much technical expertness to be altogether practical in providing ratings of voices. This implies also that there are no standard objective units for determining esthetic values in timbre. In fact there are no norms of any kind for timbre control except the subjective ones developed by musicians. It must be recognized, however, that in the absence of any scientifically derived norms for timbre, time, and intensity, the subjective ratings on the part of recognized musicians may prove to be not only of practical value in passing judgment on singers but of special value in the development of scientific methods of voice rating. As the singing of volume is correlative with the singing of pitch, intensity, or timbre, there is no need of its separate measurement. It is also improbable, therefore, that the production of volume involves any basic motor capacity peculiar only to itself.

The limited data of an experimental nature bearing on the

basic motor capacities in voice control have been secured by *Gaw* (22), who gave several motor tests to 26 practiced singers. These tests are specified as follows: simple reaction, complex reaction, motor reliability, visual serial action, auditory serial action, free action, timed action, rhythmic action, grip, and precision. The results were then compared with the scores made by the observers in the pitch tests and also with their ratings in timbre as provided by a group of voice teachers. The pitch tests included reproducing a key tone, reproducing given intervals, and singing minimal changes in pitch. Only the test in precisions seems to have any close relation to pitch control as revealed in the pitch tests. All but four of the observers obtained a percentile rank of 50 or above in the precision test with the median percentile rank of 85, and in the pitch tests the medians of the percentile ranks were 92, 99, and 94.[1] This is, of course, not an accurate comparison but it is very suggestive since the test in precision is intended to measure the qualities of accuracy and steadiness in the control of movement, qualities that are undoubtedly basic elements in the control of pitch. Further experiment may be expected to reveal that, if pitch control can be satisfactorily tested before training, the tests must be of such a nature that they will measure accuracy and steadiness of muscular control. Gaw's test in precision should be given a more extended trial and various modifications of it may well be made.

By the same method of comparing percentile ranks, the results of Gaw's precision test also showed a positive correlation with the ratings in timbre control as determined by the judgment of voice teachers. The same was true with regard to three other motor tests—timed action, rhythmic action, and grip—although it is evident that in none of the comparisons with timbre control were the correlations as marked as in the case of precision and the pitch tests. While it is obvious that no definite conclusion is warranted, the results are promising. Whatever the final determination of the basic motor capacities may be, some test of pre-

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[1] If the relationship were reduced to an index of correlation, it would probably be misleading because of the limited spread of the scores in the pitch tests.

cision promises to be a factor of the first importance in the rating of voice.

In the absence of any experimental data regarding the control of intensity and time, their underlying motor capacities can only be inferred from the nature of these functions. In the former case there appears to be a capacity for the sensitive response to pressure. In the latter case there appears to be a capacity for regulating the rate of muscular movement, and probably this would resolve itself into more specific capacities, such as motility, reaction time, timed action, and rhythmic action. Whether any of these capacities mentioned will prove to be basic as far as voice control is concerned must of course be determined by experimentation. Empirical testing may bring to light others of far greater importance although their value is not so apparent from a theoretical analysis of voice production. Experimental study must also determine the relative value of the motor capacities as compared with other capacities essential to voice control, and once determined this datum will be of the first importance in the selection and guidance of vocal talent.

Sensory Capacities

The emphasis given to the motor capacities in voice control can with equal justification be applied to certain capacities of a sensory nature. For artistic singing requires the guidance of such capacities just as much as it requires a high degree of stability in muscular adjustment. In fact, the one kind of function supplements the other. It is essential, therefore, to evaluate as far as possible the sensory, as well as the motor, equipment of the singer and to determine the degree of relationship between the two sets of factors.

The specific sensory capacities that are essential in the control of voice seem to be better known than are the specific motor capacities. The sensory phase of a singer's make-up is no doubt easier to analyze than his motor mechanism, and it also has a more extended history of investigation, which has yielded important facts. But while it seems self-evident that such specific capacities as pitch discrimination and the discrimination of inten-

sity and time have an important place in singing, their complete evaluation is as difficult as in the case of the motor function; for the same conditions imposed on the latter must be imposed on the former. And, as has already been revealed, this implies a number of obstacles that have yet to be overcome. It will be worth while, however, to consider the importance of each of the sensory capacities as far as present analyses and available experimental data permit.

Pitch discrimination. Theoretically, a singer's capacity for pitch discrimination, or pitch threshold, should largely determine the limit of his accuracy in the singing of pitch. If this assumption were true, the lowest pitch threshold would insure the most accurate pitch singing, other things being equal. This would have further significance also, due to the fact, as shown by *Smith* (95), that pitch discrimination is an elemental capacity, *i.e.,* independent of age, sex, and training. The relation between this capacity and the different forms of pitch control will now be considered in the light of results of experimental investigation.

As has been pointed out, pitch control includes four different forms or abilities: (1) reproducting a key tone, (2) reproducing a given interval, (3) singing minimal changes in pitch, and (4) sustaining a given tone at constant pitch. Indirectly these principles apply to all variants of pitch control, such as glide, vibrato, and tie. All but the last of these have been experimentally investigated with reference to the problem in hand.

The data[1] relative to 1, 2, and 3, above, warrant the following conclusions[2] for each:

(1) In data obtained in unselected groups or where the observers as a whole had had limited practice in singing, correlations and observations show low correlation between the ability to discriminate pitches and the ability to sing in pitch.[3] This may appear at first to be somewhat incongruous but,

[1] *Miles* (52), *Seashore and Mount* (91), and *Gaw* (23) each provide data on all three forms of pitch control, *i.e.,* on 1, 2, and 3, above; *Knock* (40) on 1 and 2; *Cameron* (10) on 1 only and *Cutshall* (15) on 3 only.

[2] It seems reasonable to assume that these conclusions apply also to 4 above, although a final determination must obviously come from experimental study.

[3] One of the correlations found by *Miles* (52, p. 61) involving 104 cases was r .51, p.e. .048. But Miles' procedure differed from that of the other studies in that the intervals, as well as the key tones, were sung as imitated tones. More accurate records were thereby made possible.

for untrained observers, it is too much to expect a marked correlation between two such abilities tested, for on account of lack of motor skill, they are not singing near even a threshold considerably below average. This latter condition would necessarily render even a good pitch discrimination inoperative in a number of cases. Where practice was given in the pitch singing tests, as in the investigations of *Knock* (40), *Cutshall* (15), and *Cameron* (10), accuracy was increased, and Knock found that the average error tended to approach the pitch threshold, especially in the last few tests of the series. Cutshall also found this to be true, where the intensive practice in singing minimal changes included special attention given to hearing differences in tone.

(2) In data obtained in a selected group of practiced singers (22), there is a marked relationship between the ability to discriminate pitches and the ability to sing in pitch.

The lack of a one to one relationship between the sensory test and each of the three singing tests, as was also found in *Knock's* (40) and *Cutshall's* (15) studies, even after the series of practice tests, tends to indicate that the degree of sensory accuracy (even in an elemental test) is not an absolute index of motor accuracy after training. This, however, does not imply that such an index might not of itself be of some significance even in predicting motor capacity in song. A complete agreement between the factors in question is prevented by the several variable conditions on which success in pitch singing depends. It has been experimentally determined, for example, that pitch discrimination is affected by such factors as pitch (105), duration (2), intensity (99), and timbre (40) of the tones discriminated. Likewise accuracy in pitch control is affected by the intensity (52) and the timbre (40, 52) of the tones to be sung. In addition, the mental concepts of tone employed by the singer, the reliance placed on other guiding capacities, and even physiological condition all introduce a number of variable that may even render pitch discrimination inoperative at times. Any index then that may be used to indicate the effect of pitch discrimination on pitch control must be interpreted with considerable caution, particularly when used in vocational guidance.[1] However, since pitch discrimination is perhaps one of the most important single factors in pitch singing, extensive studies of the kind carried on by Gaw are highly desirable and should reveal in more exact statistical

[1] This is probably true to some extent of all such indices.

terms than are now available the value of this capacity in the different forms of singing ability.

Intensity discrimination. While a scientific evaluation of intensity discrimination is not yet possible, the necessity of controlling intensity in song implies that this capacity is highly significant. The effective performer of intensity in song must necessarily be guided by his own hearing in regulating the shades of stress he wishes to convey. And only the capacity for precision in discriminating between appropriate differences in tonal strength will insure the desired artistic effect in intensity control. This is borne out by the data provided by *Gaw* (22). Since most of her 26 observers must be rated as singers of superior ability, which necessarily includes ability in intensity control, it is significant to note that their median percentile rank in the test for intensity discrimination was 97, the lowest rank being 61. Inasmuch as this capacity is also elemental (93) its rating is of special value in vocational guidance. Furthermore, its rating has also proved to be a fair index of the power of concentration (91).

Auditory acuity. Along with intensity discrimination auditory acuity would also appear to have a logical place among the factors of intensity control. For a tone can be properly evaluated by the singer only when it is distinctly heard. However, this capacity is probably not so important as intensity discrimination, an assumption justified by Gaw's study (22), for the reason that mere hearing of a tone does not necessarily determine its relative value with respect to other tones. But only a good ear on the part of the singer will enable him to properly adjust his tones to his auditors, to the size of rooms, or to the fastidious requirements of convention.

Time discrimination. While the time relations in song have been measured (106), the results have been limited and no attempt has been made to correlate them with any of the sensory factors that may be involved in the appreciation or execution of time. However, an accurate rendition of time in song presupposes, on the sensory side, a keen perception of time in musical relations. The time elements in artistic music consist of very

small units, some of which are measurable only in terms of hundredths of a second, and their proper observance can be assured only by means of their accurate appreciation. This implies also that the motor control involved in tone production, as precision of attack and precision of release, must be effectively guided by this capacity both where exact intervals are required and where intervals may vary to suit the esthetic judgment of the singer.

Tests of time discrimination have revealed that the capacity of sensing time is relatively independent of age, training, and intelligence (88), and therefore its measurement would be doubly significant in the selection and guidance of vocal talent.

Perception of rhythm. The full apprehension and control of time in song requires also a perception of rhythm, of which the discrimination of time forms a basic part. Time intervals of themselves are of no great avail in music unless they are combined into larger units, the frequent recurrence of which forms an essential part of musical experience. Music gains its appeal to a large extent from the rhythmic cadences of tonal movement. The effective rendition of these rhythmic units must then presuppose on the sensory side a capacity for rhythm appreciation.

The perception of rhythm in music is not a simple capacity nor wholly sensory in nature. It involves a number of elements, of which the basic ones are time discrimination, intensity discrimination, auditory imagery, motor imagery, and motor impulse (88). Each of these may be serviceably measured and the elemental nature of the two sensory capacities would render their measurement of special importance. But it would probably be most satisfactory to measure the perception of rhythm as a unit capacity.[1]

Perception of timbre. The analysis of the nature of timbre showed that timbre is virtually a complex of pitches and also to some extent a complex of intensities. This would suggest that discrimination of pitch and intensity may be among the sensory

[1] On ths point valuable advances have been made in the Iowa laboratory since this paper was written.

capacities that are essential to timbre control. Gaw's study (22) tends to confirm this expectation. But while these two capacities may aid in judging the timbre of a tone the full evaluation of timbre undoubtedly requires an element not embodied in these two capacities separately. That is, the evaluation of timbre appears to require the capacity for a synthetic appreciation of the tonal elements that make up timbre. No attempt has been made to measure this capacity in common with any form of voice rating, yet on the analogy that the perception of pitch is essential to pitch control it seems plausible to assume that the perception of timbre is essential to timbre control.

Perception of consonance. The nature of timbre and its control and particularly the nature of musical harmony implies a capacity for the keen appreciation of the consonance values of combined tones. To the vocal soloist such a capacity may not serve a very practical function, but in all other forms of singing the most esthetic effects in harmony can be attained only as the singers fully appreciate the blend effects of tones simultaneously produced. Results from a test of consonance given by *Gaw* (22) show some correlation with ratings in timbre, the respective median percentile ranks being 87 and 62, with four of the 26 observers ranking below the middle percentile.[1] If the relationship could be accurately expressed in terms of a Pearson *r,* it probably would be considerably less than .50. But whatever the true rating of the perception of consonance proves to be it will no doubt be found to be a factor of some importance in the sensory equipment of the singer.

Discrimination of kinesthetic sensations. In the absence of any objective rating that would indicate the value of kinesthetic sensations in voice control[2] the theoretical and other evidence is deserving of consideration.

If conscious attention is directed to the sensations or tensions

[1] The fact that the norms used in timbre rating were determined from the ratings of an unselected group tends to minimize the implied relationship.

[2] As kinesthetic sensations are known to function in the various forms of voluntary muscular control, ratings in the basic motor capacities may prove to be a sufficient index of the value of kinesthetic sensations in voice control.

felt in the larynx and elsewhere during vocalization it will be noticed that they vary with differences in adjustment, *i.e.*, with differences in pitch, intensity, and timbre. After practice they may be noticed to vary with very slight changes in vocal adjustment. Such a simple experiment will reveal that kinesthetic sensations are closely bound up with every adjustment of the voice and it seems probable that they constitute an important factor in voice control. It is possible that these sensations may remain quite unnoticed in the process of developing voice control, just as this seems true in attaining many other conscious ends, and still serve a valuable function. But it seems very probable that they would be of maximum value if they are consciously experienced and singers might well profit by giving them due recognition.

The above conclusion is borne out by the observations of a number of investigators, especially with reference to pitch control. *Berlage* (4) and *Knock* (40) both report that observers reproduce the pitch of their own voices more accurately than those of another, and *Miles'* (52) testimony is essentially the same. This would show that one can reproduce a tone more accurately when guided by the muscular " feel " of it than when relying on hearing alone. Of course, memory and imagery may be factors here. Berlage's general conclusion is that the kinesthetic sensations, along with auditory imagery, control the pitch of the voice more directly than do the auditory sensations. Both *Cutshall* (15) and *Knock* (40) noted that the throat sensations became more significant with practice until whenever a correct note was struck it was indicated by a " feeling of familiarity in the throat." In their opinion this was one of the main criteria for judging the accuracy of a reproduced tone. The testimony of *Klünder* (39) and *Stern* (98) is practically the same and equally emphatic.

These observations all agree that kinesthetic sensations constitute a real factor in the control of pitch in singing. And what has been said of their importance in pitch control may be said to apply equally well to their importance in the other aspects of

voice control. That they apply in the control of time may be justly inferred from the nature of the perception of time (88) and also from the nature of the perception of rhythm (75), in so far as it may be assumed that these two capacities function in time control. And as the production of timbre and intensity requires to a large extent the same motor mechanism as the production of pitch it seems plausible that if the muscular sensations function in the control of the latter they would also function in the control of the former. The observations noted above, however, have suggested that kinesthetic sensations are at least of sufficient importance to deserve recognition and in some cases they may undoubtedly be a highly serviceable factor in the development of control in singing.

As any analysis, wholly or partly theoretical, is apt to fall short of objective verification, so this analysis of the sensory aspect of voice is apt to do some injustice to fact. In some cases the inferences and conclusions will probably correspond more or less favorably to those justified by future findings; in other cases there may be considerable variance. Only empirical testing will remedy the shortcomings and such testing will undoubtedly reveal significant facts with reference to the relative importance of the different sensory capacities involved in voice, their intercorrelations, and their correlation with actual accomplishment and with the basic motor capacities.

Higher Cognitive Powers Involved in Voice Production

The most effective use of the voice requires the function of other mental powers besides the sensory and motor capacities that have been discussed. These powers are of a cognitive nature and include imagery, imagination, memory, and intelligence. The relative value of each can be indicated in only a general way, for at present their evaluation must, in most cases, be based on an analysis of vocal requirement rather than on experimental data.

Imagery. Studies in imagery have revealed that practically all persons have some capacity for imagery in all of the senses and that some type of imagery is usually more or less prominent.

This fact furnishes a theoretical basis for the assumption that imagery in some form plays a part in voice control. The nature of imagery is such that it is difficult to determine its real rôle in voice production but the above assumption has been borne out by introspective reports and such subjective ratings as have been used.

Most of the studies of imagery in voice have been made with reference to its use in pitch control. The data presented in these studies may, however, be a fair indication of the use of imagery in the control of all the other factors in voice. The data relative to pitch control justify the following conclusions:

(1) The subjective ratings[1] of auditory, motor, and visual imagery indicate a moderate correlation with ability to sing in pitch.

(2) Introspective reports[2] obtained in connection with the singing tests indicate that a large number of observers consider the auditory or the motor type of imagery an important aid in their singing. The visual type was reported to be of value in only a small percentage of cases. These reports are more significant than the subjective ratings in that they more truly reveal the real function of the image during actual singing.

(3) Even in the case of practiced singers the subjective ratings show one type of imagery to be almost as common as any other; and that all observers tend to rank high, *i.e.,* above the middle percentile, in at least one type of imagery. If the highest rank obtained in the three imagery tests were considered the representative rank, a much higher relationship would probably be found between imagery and voice control.

With due recognition of the limitations of the subjective method, it still seems justifiable to assume that imagery in some form is of value to the singer, especially in the process of acquiring voice control.

Agnew's findings (1) are of special importance in this connection. The more significant are:

(1) Subjective rating of imagery tends to be lowered by practice.

(2) "Development of imagery is correlative with growth in musical training. This may mean development in a cognitive way only and not in vividness."

(3) Auditory imagery is most vivid, and therefore of most value, during the period of attaining skill, *i.e.,* in learning to sing. "With increase of automatization it becomes more and more inconspicuous."

(4) Recognized musicians tend to consider the auditory image a fundamental part of musical talent and that it should be developed during musical training.

[1] Obtained by *Seashore and Mount* (91), *Agnew* (1) and *Gaw* (22, 23).
[2] Obtained by *Cutshall* (15) and *Knock* (40) as well as by the other investigators.

Imagination. As artistic singing is to be essentially creative so it calls for a mind that is enriched by a vivid imagination. The singer's power should transcend the mere imaging of tones to be produced and picture the ideals and sentiments that the tones are intended to convey. He should be able to convey through his vocal art a realistic representation of musical content and do so with a vital spontaneity of expression. And these two character- istics can be supplied only by a serviceable imagination.

But imagination may take form in various types, some of which are ill suited for the expression of music. Seashore there- fore points out: " It is extremely important to know whether we shall have a musician of the sensuous, the intellectual, the impul- sive, the motor, or the balanced type, and what relative degree of strength it promises. What teachers and guides in music need for their purpose is not tests, but insight into the nature and manifestations of this gift, which may well be designated as the ' spark of genius ' in the artistic mind " (88, p. 235).

Memory. Memory in its varied aspects of immediate reproduc- tion, retention, and recall has, theoretically, a very important function in attaining vocal control. For only as any given tone is accurately judged on the background of past experience can it be properly evaluated. But memory in voice control is not limited merely to the remembering of tones and the fine distinctions between them; it functions in all aspects of hearing, feeling, and rendering of tones; it consists of remembering the larger setting of relationships of which the tone is but a part—a remembering of vocal adjustments and their accompanying sensations, of feel- ings and emotions expressed within or accompanying the tone, and of ideas represented in the succession of tones. In its broad sense, memory is also practically synonymous with the capacity to learn—the capacity to learn in motor control, the capacity to understand tonal relations, and the capacity to interpret the infinite forms of tonal impression.

The capacity of memory then is one of the important criteria for judging potential power in voice control. One of its measures, a test of tonal memory, has proved its worth in the diagnosis of

vocal talent (22). But obviously no single test will suffice to adequately measure its importance. Only as one can estimate it in its manifold applications can one evaluate its full significance in any one instance.

Intelligence. A full appreciation of the use of the singing voice presupposes a musical intelligence of at least average capacity. Effective progress in the art of song can be realized only as the singer attains a clear understanding of the principles of vocal art and an intelligent mastery of the principles of tone production. And the maximum progress can be assured only as the singer also attains an adequate comprehension of the purpose and worth of music, a rich acquirement of musical ideas, and the power of reflective thinking. The fullest realization of these attainments implies an intellectual capacity undoubtedly equal to that required for success in most of the worthy callings.

A rating of general intelligence may furnish a fair index of the intelligence required in music but it needs to be supplemented with an evaluation of the richness of musical associations and with an insight into the fullness of musical appreciation.

The Emotions and the Voice

The vocal expression of emotional states has been given some recognition from time to time in our discussion of the basic factors of voice. It remains to be considered why the emotional state should constitute an expressive element in the voice—why such emotions as anger and joy, and even the minute variations in their quality and intensity, should each be reflected in vocal tone.

That the voice should become one of the means of emotional expression seems to have been ordained by biological function. *Darwin* (16) and others claim that the voice developed for the purpose of expressing emotion, beginning as a means of expressing the emotion of love or as an instrument of sex attraction. If Darwin's theory is correct it follows naturally that the vocal mechanism, being developed through and by the expression of emotion, would be directly responsive to each affective state. But apart from evolutionary theory recent physiological re-

searches (12) make it possible to state quite definitely just how emotion exerts its influence on the vocal mechanism, and therefore on vocal tone. These researches demonstrate that during any emotional experience all the vital functions of the body—circulation, breathing, digestion, glandular secretion—are more or less affected, the nature of the effect being determined by the nature and intensity of the emotion. It has also been demonstrated that all the parts of the vocal apparatus, from the diaphragm to the lips, are intimately bound up, through the autonomic system, with the function of the internal organs. The neural effect of emotional disturbance in the latter will then be transmitted to the different parts of the former. The characteristics of muscular tension throughout the vocal mechanism will thus conform to the nature of the emotional state, and the specific quality and intensity of each emotion experienced will have its counterpart in the tone expressed. A graphic representation of voice reveals the same fact—that the specific quality and intensity of the emotion experienced has its counterpart in the physical sound wave. The sound wave that leaves the singer's lips will inevitably reflect the conditions that create it.

The contribution of emotional expression to musical values still awaits scientific investigation. The ringing vibrant element (known as the vibrato) which is characteristic of the highly musical voice is probably determined, in part, by the emotional make-up of the singer but this is yet to be established. It is clear, however, that emotion has a marked effect on timbre and common observation seems to justify the assertion that, apart from physiological structure and function, emotion is the most important single factor in timbre production. Emotional expression in song, especially that of the loftier type, always touches a responsive chord in the listener. The tone with a warm emotional glow carries with it a rich connotation and a vitalizing appeal. The monotone and other types of unmusical voice are displeasing for the very reason that they are lacking the emotional element. Artistic singing probably requires the cultivation and control of

emotional experience as much as it does the cultivation and control of the vocal mechanism.

Whether the singing voice can be cultivated by means of emotional expression also awaits scientific investigation, although several systems of vocal training are based on the assumption that it does. The physiological researches already referred to offer evidence in support of this assumption. *Blanton* (7) has pointed out that emotions of the pleasant type tend to have a wholesome effect on the voice and he bases his contention on the observations of *Cannon* (12) relative to the function of the cranial and thoracico-lumbar divisions of the autonomic system. The cranial division produces the physiological conditions that underlie the pleasant emotions such as the slow, regular heart beat, the calm steady breath, and the vital muscular tone. The physiological conditions underlying the unpleasant emotions are quite the opposite; breathing is especially disturbed and the conditions of muscular tension are such as to interfere with the most agreeable function of the vocal mechanism. Under these latter conditions the voice can produce only harsh and unpleasant tones, while under the former the feeling of well being so affects the vocal apparatus that, according to *Blanton* (7), the voice is then at its best. Whether this has a permanent effect on the voice is yet to be determined. It may be found that the more agreeable emotions constitute only a favorable condition for the cultivation of artistic tone. A practical solution of this problem may have far-reaching consequence and may also aid in laying a firm foundation for a scientific training of voice.

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